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FINAL ENVIRONMENTAL IMPACT STATEMENT

on a

Proposed Nuclear Weapons Nonproliferation Policy Concerning Foreign Research Reactor Spent Nuclear Fuel

Appendix E
Evaluation of Human Health Effects of Overland Transportation

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Appendix E
Evaluation of Human Health Effects of Overland Transportation

E.1 Introduction

The overland transportation of any commodity involves a risk to both transportation crew members and members of the public. This risk results directly from transportation-related accidents and indirectly from the increased levels of pollution from vehicle emissions, regardless of the cargo. The transportation of certain materials, such as hazardous or radioactive waste, can pose an additional risk due to the unique nature of the material itself. In order to permit a complete appraisal of the environmental impacts of the proposed action and alternatives, the human health risks associated with the overland transportation of foreign research reactor spent nuclear fuel have been assessed.

This appendix provides an overview of the approach used to assess the human health risks that may result from the overland transportation of foreign research reactor spent nuclear fuel. The appendix includes discussion of the scope of the assessment, analytical methods used for the risk assessment (i.e., computer models), important assessment assumptions, determination of potential transportation routes, and presents the results of the assessment. In addition, to aid in the understanding and interpretation of the results, specific areas of uncertainty are described, with an emphasis on how the uncertainties may affect comparisons of the alternatives.

The approach used in this appendix is modeled after that used in the Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Final Environmental Impact Statement (SNF&INEL Final EIS) (DOE, 1995). The SNF&INEL Final EIS did not perform as detailed an analysis on the specific actions taken for foreign research reactor spent nuclear fuel because of the breadth necessary to analyze the entire spent fuel management program. However, the fundamental assumptions used in this analysis are consistent with those used in the SNF&INEL Final EIS (DOE, 1995), and the same computer codes and generic release and accident data are used.

The risk assessment results are presented in this appendix in terms of "per-shipment" risk factors, as well as for the total risks associated with each alternative. Per-shipment risk factors provide an estimate of the risk from a single spent nuclear fuel shipment between a specific origin and destination. They are calculated for all possible origin and destination pairs for each spent nuclear fuel type. The total risks for a given alternative are found by multiplying the expected number of shipments by the appropriate per-shipment risk factors. This approach provides maximum flexibility for determining the risks for a large number of potential alternatives.

E.2 Scope of Assessment

The scope of the overland transportation human health risk assessment, including the alternatives and options, transportation activities, potential radiological and nonradiological impacts, and transportation modes considered, is described below. Additional details of the assessment are provided in the remaining sections of the appendix.

Proposed Action and Alternatives: The transportation risk assessment conducted for this EIS estimates the human health risks associated with the transportation of spent nuclear fuel for a number of management and implementation alternatives. The alternatives differ primarily in the number and location of possible ports of entry and Phase 1 management sites (storage sites that would be used until a repository was ready). The alternatives considered are described in detail in Chapter 2 of this EIS.

For transportation assessment purposes, each option is defined as an individual or pair of U.S. Department of Energy (DOE) sites used for initial management and an individual or pair of DOE sites used for final interim management. The transportation risk assessment determines risks by considering the total amount of spent nuclear fuel shipped over each representative route. The assessment takes into account differences in the physical and radiological properties of spent nuclear fuel types and characteristics of the potential routes to and between sites.

A large number of potentially applicable marine ports of entry and Canadian border crossings, including commercial and military ports on the Atlantic, Pacific, and Gulf of Mexico coasts are considered in this risk analysis. The port selection process is described in Appendix D. The Canadian border crossing points are representative points based on a qualitative judgment of previously used shipment routes (NRC, 1993). The alternatives in this EIS define the acceptance of the fuel, while the SNF&INEL Final EIS (DOE, 1995) alternative selected defines the DOE site or sites that would receive foreign research reactor spent nuclear fuel; and the options identified in this EIS define the various ways in which the foreign research reactor spent nuclear fuel could be handled to meet the SNF&INEL Final EIS selected alternative.

Transportation-Related Activities: The transportation risk assessment is limited to estimating the human health risks incurred during the overland transportation of spent nuclear fuel for each alternative. The risks to workers or to the public during spent nuclear fuel loading, unloading, and handling prior to or after shipment are not included in the overland transportation assessment, they are addressed in Appendices C and D. Similarly, the transportation risk assessment does not address possible impacts from increased transportation levels on local traffic flow, noise levels, or infrastructure.

Radiological Impacts: For each alternative, radiological risks (i.e., those risks that result from the radioactive nature of the spent nuclear fuel) are assessed for both incident-free (i.e., normal) and accident transportation conditions. The radiological risk associated with incident-free transportation conditions would result from the potential exposure of people to external radiation in the vicinity of a loaded shipment. The radiological risk from transportation accidents would come from the potential release and dispersal of radioactive material into the environment during an accident and the subsequent exposure of people through multiple exposure pathways (i.e., exposure to contaminated ground or air, or ingestion of contaminated food).

All radiological-related impacts are calculated in terms of committed dose and associated health effects in the exposed populations. The radiation dose calculated is the total effective dose equivalent (10 CFR Part 20), which is the sum of the effective dose equivalent (EDE) from external radiation exposure and the 50-yr committed effective dose equivalent from internal radiation exposure. Radiation doses are presented in units of person-rem for collective populations and rem for individuals. The impacts are further expressed as health risks in terms of latent cancer fatalities (LCF) and cancer incidence in exposed populations. The health risk conversion factors (expected health effects per dose absorbed) were derived from International Commission on Radiological Protection Publication 60 (ICRP, 1991).

Nonradiological Impacts: In addition to the radiological risks posed by overland transportation activities, vehicle-related risks are also assessed for nonradiological causes (i.e., related to the transport vehicles and not the radioactive cargo) for the same transportation routes. The nonradiological transportation risks are independent of the radioactive nature of the cargo and would be incurred for similar shipments of any commodity. The nonradiological risks are assessed for both incident-free and accident conditions. Nonradiological risks during incident-free transportation conditions would be caused by potential exposure to increased vehicle exhaust emissions. The nonradiological accident risk refers to the potential occurrence of transportation accidents that directly result in fatalities unrelated to the shipment cargo. State-specific transportation fatality rates are used in the assessment. Nonradiological risks are presented in terms of estimated fatalities.

Transportation Modes: All spent nuclear fuel shipments have been assumed to take place either by truck or rail transportation modes. Per-shipment risk factors are presented separately for truck and rail modes. For the alternatives, risks have been calculated separately for all truck and all rail options, although the actual transportation operation for a selected alternative may involve a combination of the two modes.

Barge transport has certain disadvantages. First, barge transport limits site and port selection for both the SNF&INEL Final EIS and this EIS to Savannah River Site (available both phases) and Hanford Site (available in Phase 2 only). These sites are only served by the ports of Savannah, GA and Portland, OR, respectively. Additionally, barge transportation would require additional intermodal transfers at the port and at the site. At the port, the cask would be removed from the ocean-going vessel and moved by truck to the barge terminal for loading onto a barge. When the barge arrives at the DOE site, the cask would have to be moved to a truck for transport across the site to the receiving basin. Other reasons for not using barge transportation include DOE's lack of extensive experience in shipping casks via barge, the lack of alternative routes, and low speeds. DOE, however, has performed a scoping analysis of barge transportation to assess its relative impacts.

Receptors: Transportation-related risks are calculated and presented separately for workers and members of the general public. The workers considered are truck and rail crew members involved in the actual overland transportation of spent nuclear fuel. The general public includes all persons who could be exposed to a shipment while it is moving or stopped en route. Potential risks are estimated for the collective populations of exposed people, as well as for the hypothetical maximally exposed individual (MEI). The collective population risk is a measure of the radiological risk posed to society as a whole by the alternative being considered. As such, the collective population risk is used as the primary means of comparing various alternatives.

Cumulative Impacts: The cumulative impacts of the transportation of foreign research reactor spent nuclear fuel are calculated and presented as a relative proportion of those described in the SNF&INEL Final EIS (DOE, 1995). The collective dose to the general population and workers is the measure used to quantify cumulative transportation impacts.

E.3 Spent Nuclear Fuel Packaging and Representative Shipment Configurations

Regulations that govern the transportation of radioactive materials are designed to protect the public from the potential loss or dispersal of radioactive materials as well as from routine radiation doses during transit. The primary regulatory approach to ensure safety is through the specification of standards for the packaging of radioactive materials. Because packaging represents the primary barrier between the radioactive material being transported and radiation exposure to the public and the environment, packaging requirements are an important consideration for the transportation risk assessment. Regulatory packaging requirements are discussed briefly below and in Chapter 5. In addition, the representative packaging and shipment configurations assumed for this EIS are described.

E.3.1 Packaging Overview

Although several Federal and State organizations are involved in the regulation of radioactive waste transportation, primary regulatory responsibility resides with the U.S. Department of Transportation and the U.S. Nuclear Regulatory Commission (NRC). All transportation activities must take place in accordance with the applicable regulations of these agencies specified in 49 Code of Federal Regulations (CFR) Part 173 and 10 CFR Part 71.

Transportation packaging for radioactive materials must be designed, constructed, and maintained to ensure that the packages will contain and shield their contents during normal transport conditions. For more highly radioactive material, such as spent nuclear fuel, they must contain and shield their contents in the event of severe accident conditions. The type of packaging used is determined by the total radioactive hazard presented by the material within the packaging. The basic types of packaging required by the applicable regulations are designated as Type A, Type B, or "strong and tight".

"Strong and tight" packages are designed such that no radioactive material will leak or be released during transportation. They can only be used for low-specific-activity material. Type A packaging must withstand the conditions of incident-free transportation without the loss or dispersal of the radioactive contents. Incident-free transportation refers to all conditions of transportation except those that result from accidents or sabotage. Approval of Type A packaging is achieved by demonstrating that the packaging can withstand specified test conditions which are intended to simulate incident-free transportation conditions. Type A packaging, typically a 55-gallon (gal) drum or standard waste box, is commonly used to transport wastes having low activities of radioactive material.

The transportation of spent nuclear fuel requires the use of Type B packaging. In addition to meeting the standards for Type A packaging, Type B packaging must provide a high degree of assurance that even in severe accidents the integrity of the package will be maintained with essentially no loss of the radioactive contents or serious impairment of the shielding capability. Type B packaging must satisfy stringent testing criteria specified in 10 CFR Part 71. The testing criteria were developed to simulate severe hypothetical accident conditions, including impact, puncture, fire, and water immersion. The massive casks used to transport spent nuclear fuel represent the most widely recognized Type B packaging.

For risk assessment purposes, it is important to note that all packaging of a given type is designed to meet the same performance criteria. Therefore, two spent nuclear fuel casks of different designs would be expected to perform similarly during incident-free and accident transportation conditions. The specific cask selected, however, will determine the total number of shipments necessary to transport a given quantity of spent nuclear fuel.

External radiation allowed to escape from a package must be below specified limits that minimize the exposure of the handling personnel and general public. The foreign research reactor spent nuclear fuel shipments would be handled only by the shipper and the receiver, an arrangement referred to as an "exclusive-use" shipment. For these types of shipments, the external radiation dose rate during normal transportation conditions must be maintained below the following limits of 49 CFR Part 173:

- 10 mrem per hr at any point 2 meters (m) (6.6 ft) from the vertical planes projected by the outer lateral surfaces of the transport vehicle (referred to as the regulatory limit throughout this document), and
- 2 mrem per hr in any normally occupied position in the transport vehicle.

Although additional restrictions apply to package surface radiation levels, these restrictions are not important for the transportation radiological risk assessment.

The NRC recently issued revised regulations, 10 CFR Part 71, governing the transportation of radioactive materials. These regulations become effective on April 1, 1996 (NRC, 1995). The revised regulations conform with those of the International Atomic Energy Agency and current legislative requirements. The revised regulations affecting "Type B" casks require that a spent nuclear fuel transportation cask with activity greater than one million curies (Ci) be designed and 290 psi, or immersion in 200 m (656 ft) of water, for a period of not less than one hour without collapse, buckling, or allowing water to leak into the cask.

E.3.2 Packaging and Representative Shipment Configurations for Foreign Research Reactor Spent Nuclear Fuel

To conduct the overland transportation risk assessment, assumptions must be made concerning the types of packaging, transport vehicles, and shipment capacities that could be used for future spent nuclear fuel shipments. In all cases, it is assumed that spent nuclear fuel would be characterized, treated, packaged, and labeled in accordance with applicable regulations prior to shipment.

The transportation of all foreign research reactor spent nuclear fuel would take place in casks certified by foreign competent authorities and revalidated by Department of Transportation in accordance with 49 CFR 173. In addition, it is assumed that only exclusive-use vehicles would be used. Highway transportation is assumed to take place by legal weight heavy-haul combination (tractor-trailer) trucks. Rail transportation is assumed to take place by regular freight train service.

E.3.3 Description of Transportation Activities

The proposed action could involve transporting foreign research reactor spent nuclear fuel from the ports of entry (both marine ports and Canadian border crossings) to DOE sites, and could involve transporting foreign research reactor spent nuclear fuel between DOE sites. The interim management site or sites for the foreign research reactor spent nuclear fuel in the United States have been determined on the basis of the SNF&INEL Final EIS (DOE, 1995).

In this section, the assumptions and logic used to model the transportation requirements for the basic implementation of Management Alternative 1 of the proposed action are described. In general, the same assumptions are used to analyze the management and implementation alternatives. Therefore, the transportation requirements for management and implementation alternatives will be described in relation to the basic implementation.

Certain assumptions are required in order to simply and consistently describe the manner in which foreign research reactor spent nuclear fuel would be transported to the sites. The shipments were divided into east coast and west coast shipments, depending on the country of origin. Spent nuclear fuel shipments from Europe, Africa, the Middle East and parts of South and Central America were designated as east coast shipments, and all others were designated as west coast shipments. Shipments from Canada were assumed to enter the United States from either an eastern or western point of entry, depending on the Canadian point of origin. Under these assumptions, the east coast would receive approximately 535 cask shipments and the west coast approximately 186 cask shipments. Approximately 116 shipments from Canada would arrive in the eastern United States.

Regarding foreign research reactor spent nuclear fuel transportation, the SNF&INEL Final EIS (DOE, 1995) analyzes the use of any one of five candidate sites and seven distinct combinations of sites. Eight of the alternatives involve sites that could not be ready to accept spent nuclear fuel at the onset of the foreign research reactor spent nuclear fuel program. Therefore, a two-phased approach is assumed using one or both of the sites that are ready to accept spent nuclear fuel (Savannah River Site and Idaho National Engineering Laboratory) as a near-term management location. Phase 1 is defined, for the purposes of analyzing transportation, as the period of time in which shipments of foreign research reactor spent nuclear fuel are transported to a near-term management site. For analytical purposes, Phase 1 is assumed to last from the beginning of 1996 to the beginning of 2006.

The amount of fuel that would arrive in Phase 1 versus Phase 2 cannot be precisely determined at this time. In order to proceed with the risk analysis, it is necessary to make assumptions based on the available information. The total number of casks that would be required to transport the 22,700 spent fuel elements is estimated to be 837, per Appendix B. The split between Phase 1 and Phase 2 depends on the rate at which casks are received and the time the Phase 2 site(s) is ready to receive fuel. For calculational purposes, the casks are assumed to arrive at a uniform rate, and the Phase 2 site(s) is assumed to be ready 10 years after the implementation of the policy.

The disposition of foreign research reactor spent nuclear fuel during Phase 1 is analyzed in this EIS. Logically, Phase 1 could entail any one of four options: A) splitting foreign research reactor spent nuclear fuel by fuel type [TRIGA (which stands for Training, Research, and Isotope reactors built by General Atomic) to Idaho National Engineering Laboratory and Aluminum-based to Savannah River Site], B) splitting the spent nuclear fuel geographically by port of entry, C) transporting all spent nuclear fuel to Idaho National Engineering Laboratory, or D) transporting all spent nuclear fuel to Savannah River Site. Not all Phase 1 strategies are consistent with all Phase 2 strategies.

Phase 2 begins when Oak Ridge Reservation, Hanford Site, or Nevada Test Site would be ready to receive fuel from ports and, when applicable, from a DOE site being used for near-term management. In all cases, Phase 2 is dependent on decisions based on the SNF&INEL Final EIS (DOE, 1995). During Phase 2, all foreign research reactor spent nuclear fuel arriving at ports of entry would be transported to the appropriate site. Additionally, intersite shipments from the near-term management site could also be arriving at the SNF&INEL Final EIS selected site(s).

The following is a description of the shipping program, organized by SNF&INEL Final EIS (DOE, 1995) alternatives:

No Action - DOE cannot accept foreign research reactor spent nuclear fuel under this alternative.

Decentralization - Foreign research reactor spent nuclear fuel arriving on the east coast would be transported to Savannah River Site, and foreign research reactor spent nuclear fuel arriving on the west coast would be transported to Idaho National Engineering Laboratory. Since both Idaho National Engineering Laboratory and Savannah River Site are capable of receiving fuel in late 1995, there is no need for a two-phase program or intersite shipments. The total number of shipments for this alternative would be approximately 837. Savannah River Site would receive 651 casks from the east, and Idaho National Engineering Laboratory would receive 186 casks from the west. The transportation under this alternative is illustrated in Figure E-1. No intersite shipment would be anticipated under this single-phased alternative.

Figure E-1 Decentralization: Spent Nuclear Fuel to Idaho National Engineering Laboratory and Savannah River Site

1992-1993 Planning Basis - The SNF&INEL Final EIS (DOE, 1995) provides no specific guidance for foreign research reactor spent nuclear fuel. The transportation analysis in the SNF&INEL Final EIS assumed that half the foreign research reactor spent nuclear fuel would be transported to Idaho National Engineering Laboratory and half to Savannah River Site. The disposition of foreign research reactor spent nuclear fuel could correspond to Decentralization (described above), Regionalization (described below), Centralization to Idaho National Engineering Laboratory or Savannah River Site (described below), or an arbitrary split as described in the SNF&INEL Final EIS (DOE, 1995).

Regionalization - There are two distinct subalternatives under Regionalization: Regionalization by Fuel Type, and Regionalization by Geography. These subalternatives are described below.

Regionalization Subalternative A - Under Regionalization by Fuel Type, the foreign research reactor spent nuclear fuel would be split by fuel type, regardless of the port of entry. The TRIGA fuel would be shipped to Idaho National Engineering Laboratory and the aluminum-based Material Test Reactor (MTR) fuel would be shipped to Savannah River Site. Savannah River Site would receive 675 casks of fuel: 544 from the east and 131 from the west. Idaho National Engineering Laboratory would receive 162 casks of fuel: 107 from the east and 55 from the west. The transportation under this alternative is illustrated in Figure E-2. No intersite shipment would be anticipated under this single-phased alternative.

Regionalization Subalternative B - Under Regionalization by Geography, foreign research reactor spent nuclear fuel would be distributed between an Eastern Regional Site (Oak Ridge Reservation or Savannah River Site) and a Western Regional Site (either Hanford Site, Idaho National Engineering Laboratory, or Nevada Test Site). The foreign research reactor spent nuclear fuel arriving at an eastern port would go to the Eastern Regional Site, and the foreign research reactor spent nuclear fuel arriving at a western port would go to the Western Regional Site. If the chosen sites were Savannah River Site and Idaho National

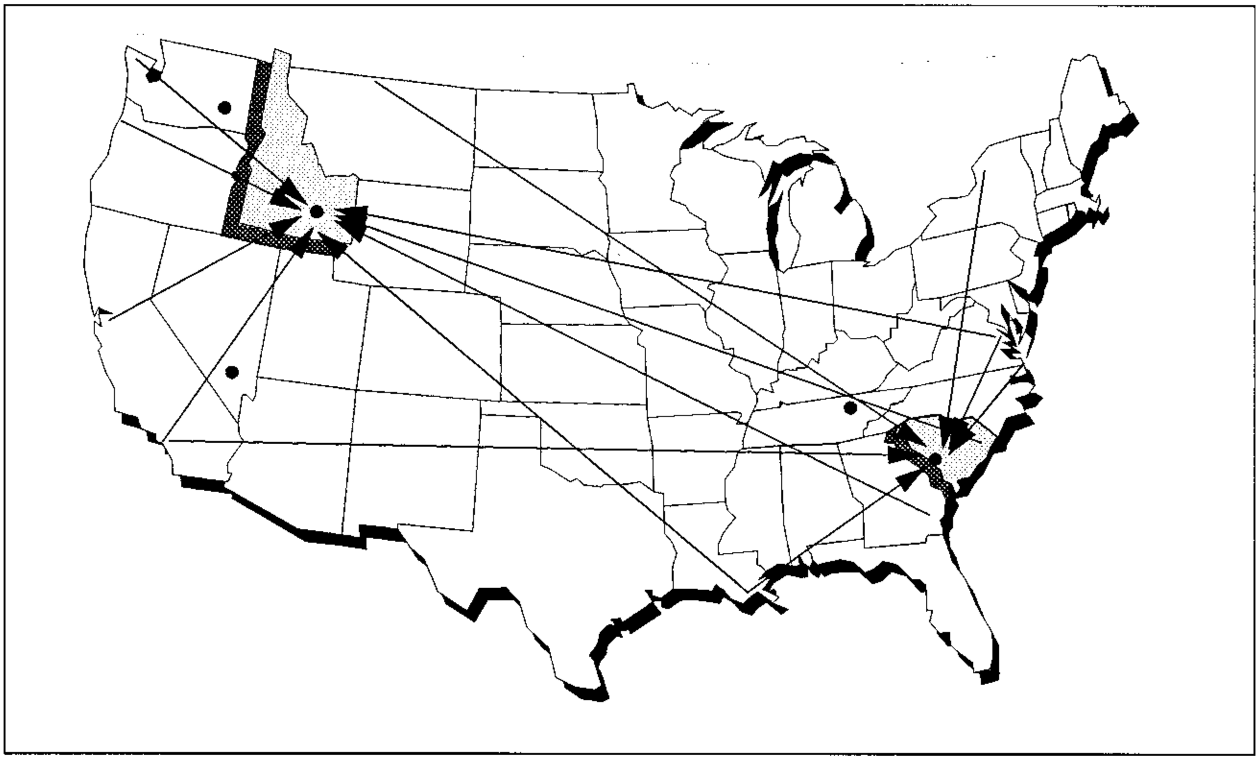

Figure E-2 1992/1993 Regionalization by Fuel Type: TRIGA Spent Nuclear Fuel to Idaho National Engineering Laboratory and MTR Spent Nuclear Fuel to Savannah River Site

Engineering Laboratory, the transportation would be the same as that described in the Decentralization Alternative and Figure E-2. No intersite shipment would be anticipated under this single-phased alternative.

A two-phased program would be required if a site other than Idaho National Engineering Laboratory or Savannah River Site were selected as a regional site under this programmatic alternative. The remaining possible site pairs for Regionalization are Idaho National Engineering Laboratory/Oak Ridge Reservation, Nevada Test Site/Savannah River Site, Nevada Test Site/Oak Ridge Reservation, Hanford Site/Savannah River Site, and Hanford Site/Oak Ridge Reservation. Splitting fuel by both geography and fuel type was considered as a logical Phase 1 approach for each site pair, but transporting all fuel to Savannah River Site or Idaho National Engineering Laboratory for near-term management was not considered for the following reasons:

- If Idaho National Engineering Laboratory were selected as the Western Regional Site, and Savannah River Site were not selected as the Eastern Regional Site, it would not be reasonable to ship all foreign research reactor spent nuclear fuel to Savannah River Site during Phase 1. Since Idaho National Engineering Laboratory is currently capable of receiving fuel and is much closer to west coast ports, it would be unreasonable to ship all fuel across the country to Savannah River Site only to move the fuel again. However, the option to ship all MTR fuel to Savannah River Site, for onsite logistical reasons, is a logical Phase 1 option even if Savannah River Site is not an ultimate interim management location. Thus, shipment of all fuel to SRS during Phase 1 was not considered reasonable if Idaho National Engineering Laboratory were to be chosen as the Western Regional Site.

- Conversely, if Savannah River Site were selected as the Eastern Regional Site, and Idaho National Engineering Laboratory were not selected as the Western Regional Site, it would not be reasonable to ship all foreign research reactor spent nuclear fuel to Idaho National Engineering Laboratory during Phase 1. Since Savannah River Site is currently capable of receiving fuel and is much closer to east coast ports, it would be unreasonable to ship all fuel across the country to Idaho National Engineering Laboratory only to move the fuel again. However, the option to ship all TRIGA fuel to Idaho National Engineering Laboratory, for onsite logistical reasons, is a logical Phase 1 option, even if Idaho National Engineering Laboratory is not an ultimate interim management location. Thus, shipment of all fuel to Idaho Engineering National Laboratory during Phase 1 was not considered reasonable if Savannah River Site were to be chosen as the Eastern Regional Site.

Figures E-3 through E-7 show the transportation schemes for site pairs Idaho National Engineering Laboratory/Oak Ridge Reservation, Nevada Test Site/Savannah River Site, Nevada Test Site/Oak Ridge Reservation, Hanford Site/Savannah River Site, and Hanford Site/Oak Ridge Reservation, respectively. The origins of the arrows representing shipments on the figures are selected for illustrative purposes, not to show specifically selected ports. Shipments would be expected to arrive at eastern, western, and Gulf Coast ports, and from eastern and western Canada. Because of their relative proximity to eastern sites, Gulf Coast ports are assigned the same transportation schemes as east coast ports. Note that there is no TRIGA fuel in Canada, so there is no planned route from Canada to Idaho National Engineering Laboratory for the Regionalization by Fuel Type alternative.

The number of shipments in the basic implementation for each site pair is described in Table E-1. The number of intersite shipments is based on the assumption that spent nuclear fuel arriving from foreign countries in small casks would be rearranged such that intersite shipments could be made in larger casks. The fuel assemblies would be cut to more efficient shapes, the fuel would be older and, thus, less radioactive and would produce less heat. For analysis purposes, it is assumed that the amount of foreign research reactor spent nuclear fuel originally shipped in four of the casks used for importing fuel could be shipped in one intersite truck cask. Rail shipment allows the use of even larger casks; and, thus, it is assumed that 10 cask loads of foreign research reactor spent nuclear fuel could be intersite shipped in 1 rail cask. Since the potential shipments would be scheduled to occur at least 10 years in the future, it is difficult to predict what casks would be used. Appendix B describes a variety of candidate casks. DOE would use fewer but larger shipments when shipping from site-to-site.

Centralization - Any one of the five DOE sites could be chosen by the SNF&INEL Final EIS (DOE, 1995) for receipt of all foreign research reactor spent nuclear fuel. If that site were Idaho National Engineering Laboratory or Savannah River Site, a two-phased approach would not be necessary. From the beginning of the program, all fuel could be accepted at either of these sites. Figures E-8 and E-9 describe the single-phase centralization options to Idaho National Engineering Laboratory and Savannah River Site, respectively.

However, a two-phase program would be required if the site selected were Hanford Site, Oak Ridge Reservation, or Nevada Test Site, none of which would be ready to receive foreign research reactor spent nuclear fuel at the beginning of the program. The option for execution of Phase 1 shipments is assumed to be independent from Phase 2 and the chosen SNF&INEL Final EIS (DOE, 1995) alternative. As with the Regionalization options, during Phase 1, DOE could choose to divide the fuel by either geography or fuel type between the two initially-capable DOE sites (Idaho National Engineering Laboratory and Savannah River Site). Alternatively, all fuel could be initially shipped to Idaho National Engineering Laboratory or Savannah River Site. Figures E-8 through E-12 show the transportation schemes for all five sites. The

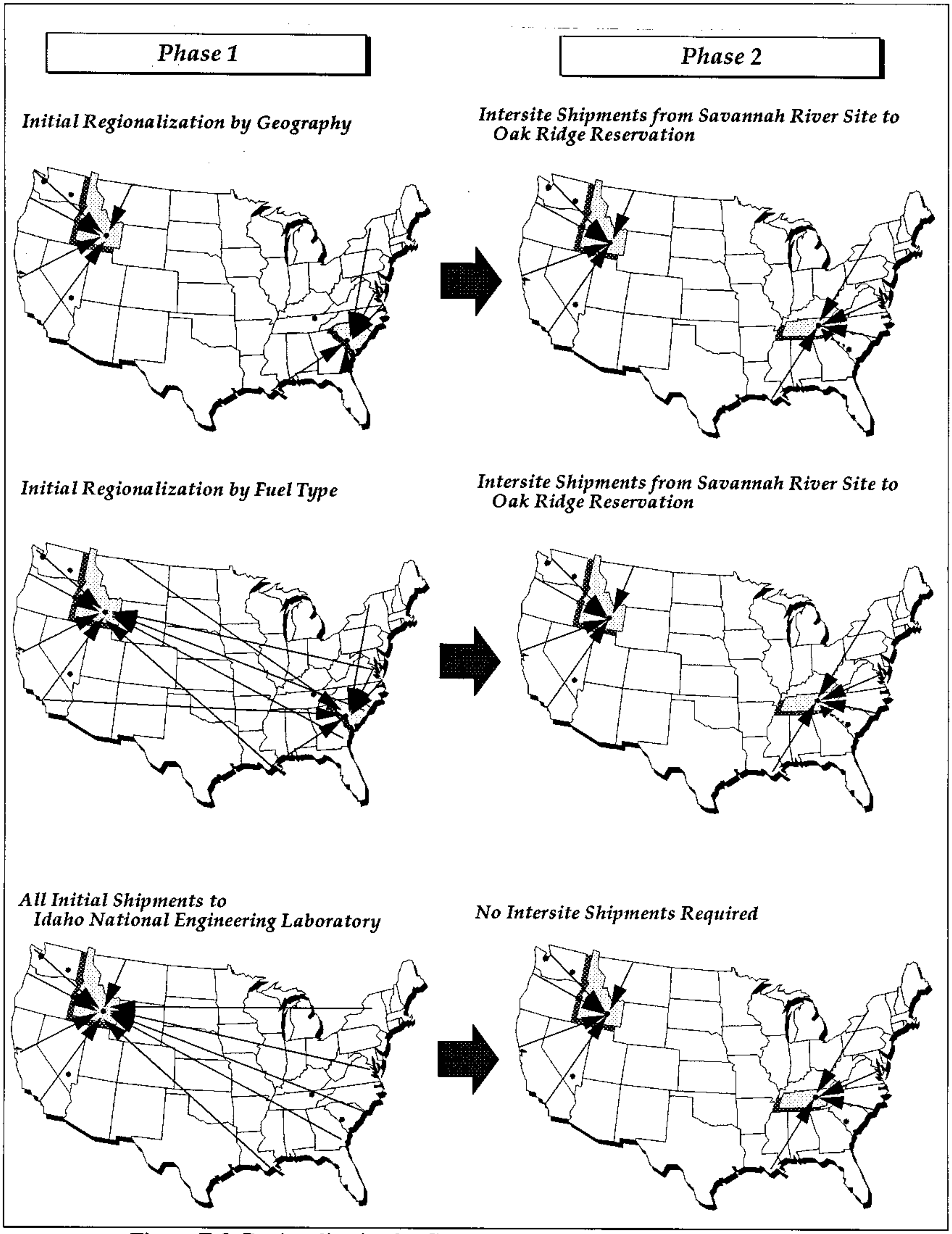

Figure E-3 Regionalization by Geography to Idaho National Engineering Laboratory and Oak Ridge Reservation

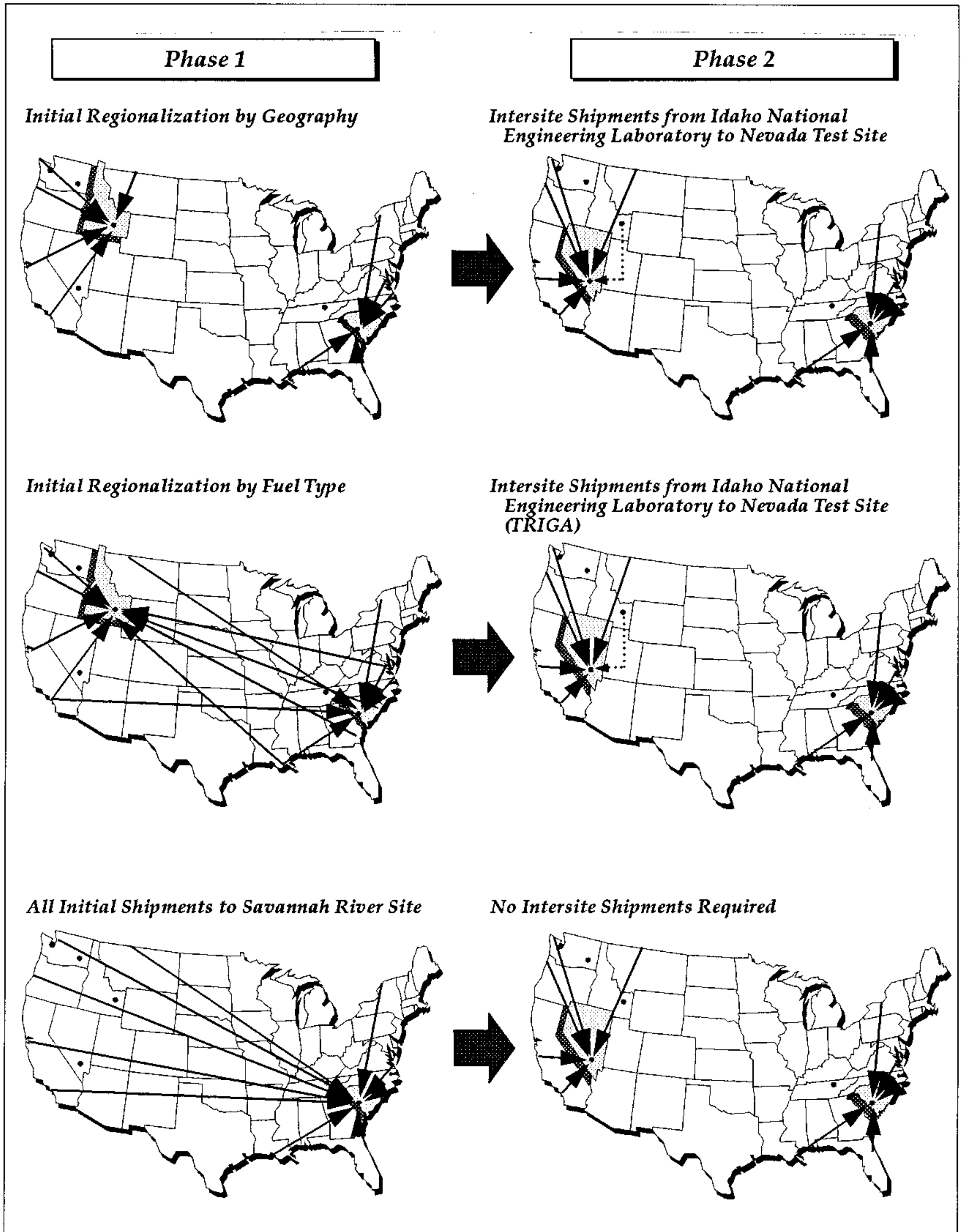

Figure E-4 Regionalization by Geography to Nevada Test Site and Savannah River Site

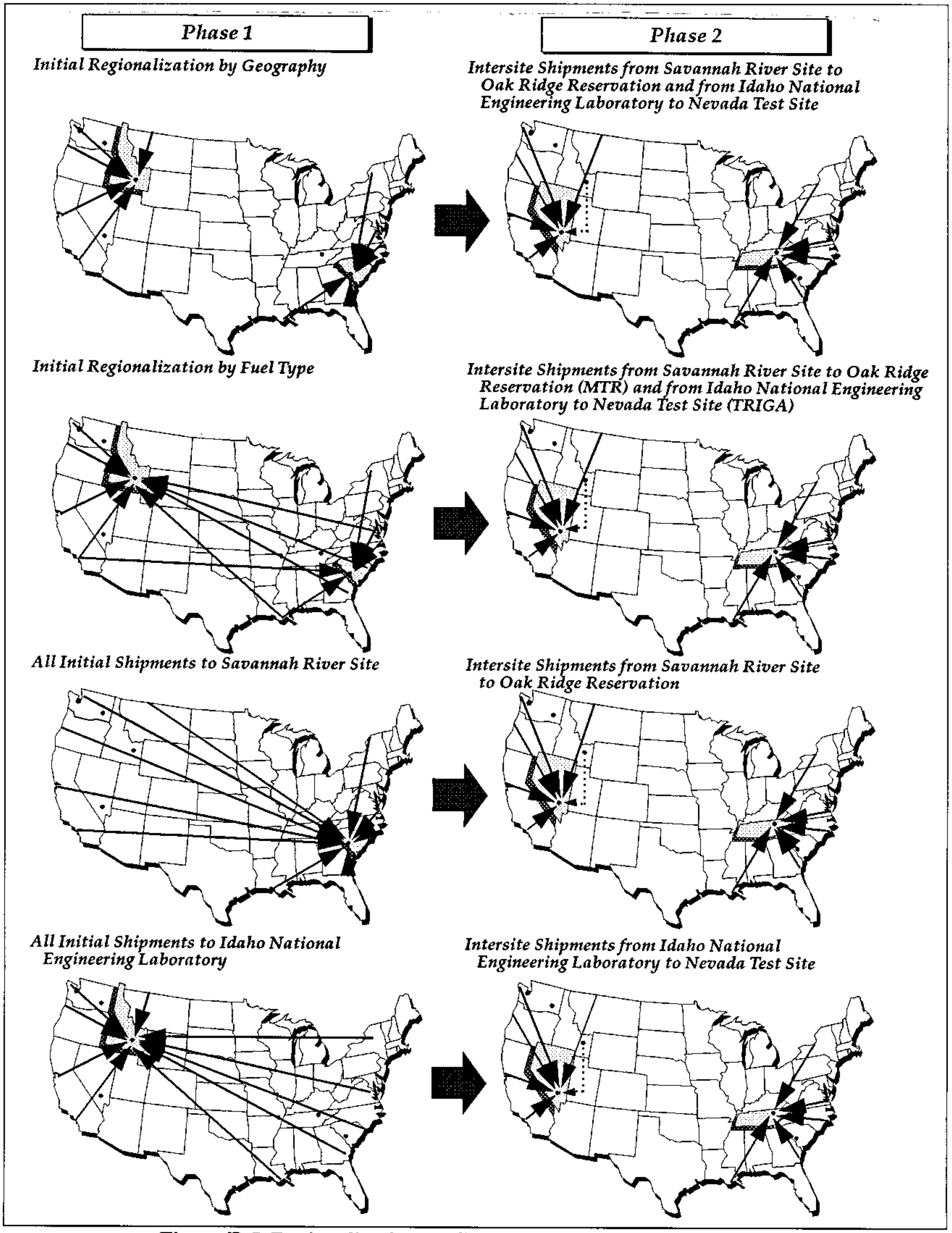

Figure E-5 Regionalization by Geography to Nevada Test Site and Oak Ridge Reservation

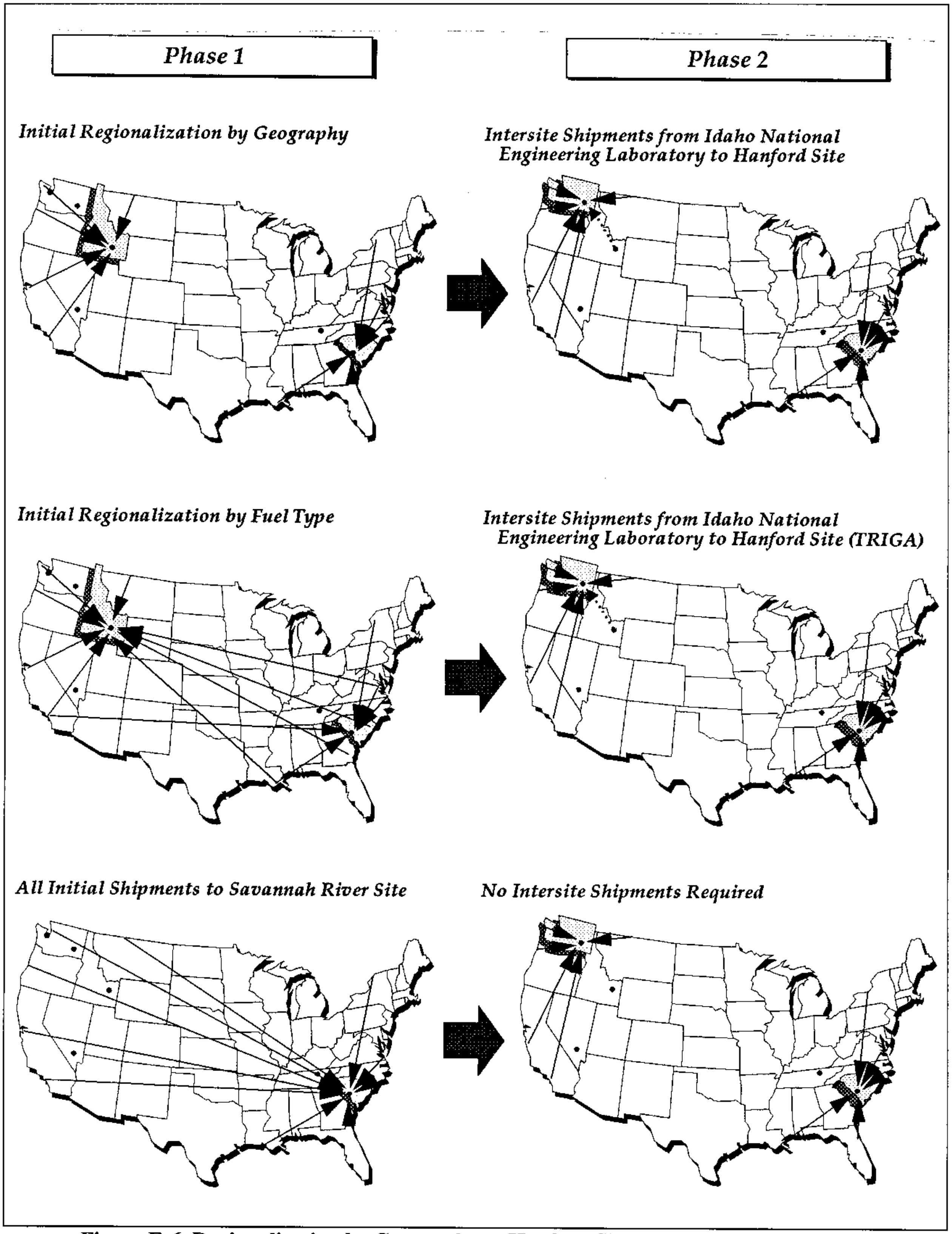

Figure E-6 Regionalization by Geography to Hanford Site and Savannah River Site

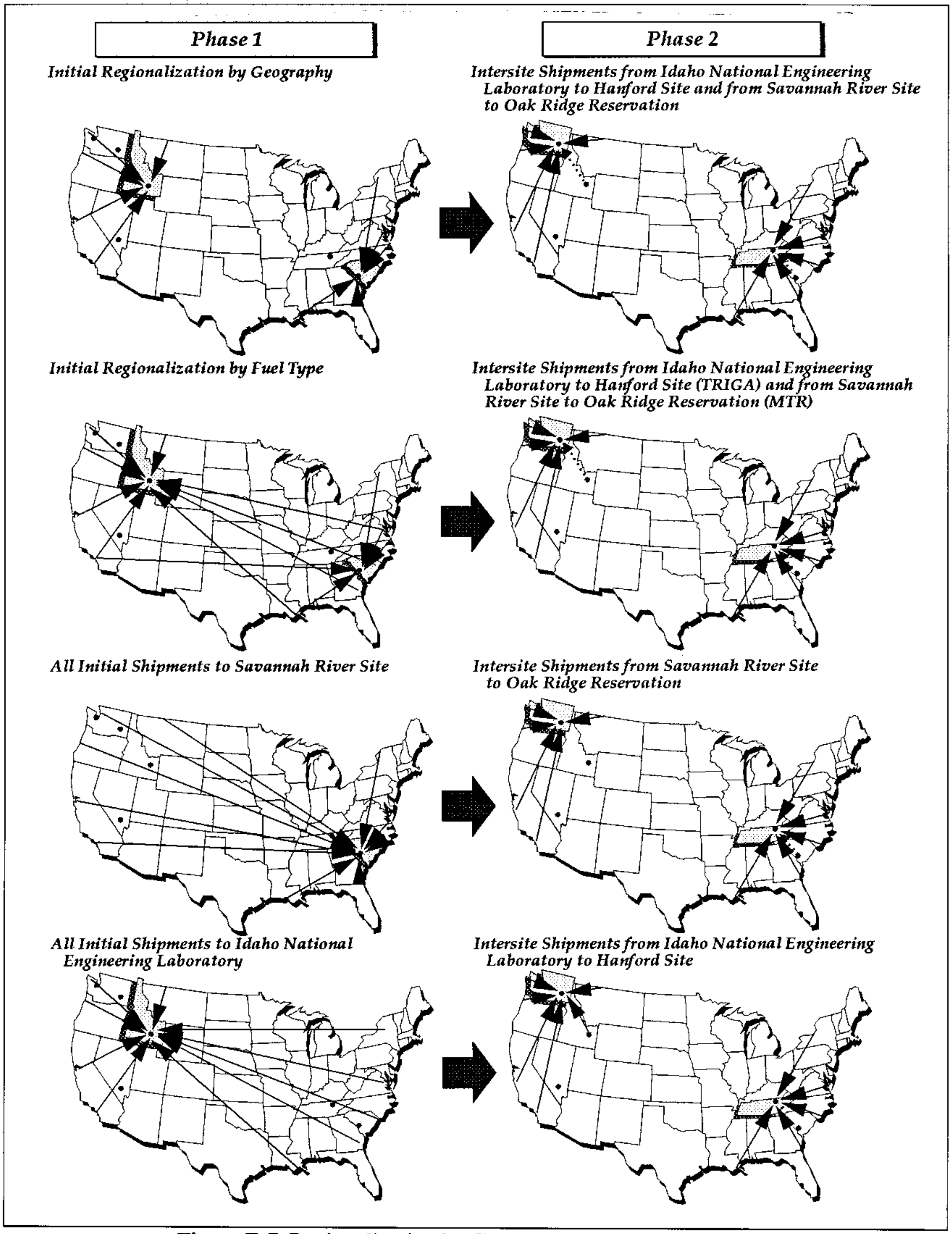

Figure E-7 Regionalization by Geography to Hanford Site and Oak Ridge Reservation

Table E-1 Shipment Summary for Regionalization Alternatives

Spent Nuclear Fuel Site Option	Phase 1 Approach	Phase 1 Port-to-Site Shipments	Site-to-Site Shipments[a]	Phase 2 or Port-to-Final Site Shipments	Total Number of Shipments
INEL/ORR	Geographic	East to SRS: 501 West to INEL: 143	SRS to ORR: 126/51	East to ORR: 150 West to INEL: 43	963/888
	By Fuel	MTR to SRS: 520 TRIGA to INEL: 124	SRS to ORR: 130/52	East to ORR: 150 West to INEL: 43	967/889
	All to INEL	644	None	East to ORR: 150 West to INEL: 43	837
NTS/SRS	Geographic	East to SRS: 501 West to INEL: 143	INEL to NTS: 36/15	East to SRS: 150 West to NTS: 43	873/852
	By Fuel	MTR to SRS: 520 TRIGA to INEL: 124	INEL to NTS: 31/13	East to SRS: 150 West to NTS: 43	868/850
	All to SRS	644	None	East to SRS: 150 West to NTS: 43	837
NTS/ORR	Geographic	East to SRS: 501 West to INEL: 143	SRS to ORR: 126/51 INEL to NTS: 36/15	East to ORR: 150 West to NTS: 43	999/903
	By Fuel	MTR to SRS: 520 TRIGA to INEL: 124	SRS to ORR: 130/52 INEL to NTS: 31/13	East to ORR: 150 West to NTS: 43	998/902
	All to SRS	644	SRS to ORR: 161/65	East to ORR: 150 West to NTS: 43	998/902
	All to INEL	644	INEL to NTS: 161/65	East to ORR: 150 West to NTS: 43	998/902
HS/SRS	Geographic	East to SRS: 501 West to INEL: 143	INEL to HS: 36/15	East to SRS: 150 West to HS: 43	873/852
	By Fuel	MTR to SRS: 520 TRIGA to INEL: 124	INEL to HS: 31/13	East to SRS: 150 West to HS: 43	868/850
	All to SRS	644	None	East to SRS: 150 West to HS: 43	837
HS/ORR	Geographic	East to SRS: 501 West to INEL: 143	SRS to ORR: 126/51 INEL to HS: 36/15	East to ORR: 150 West to HS: 43	999/903
	By Fuel	MTR to SRS: 520 TRIGA to INEL: 124	SRS to ORR: 130/52 INEL to HS: 31/13	East to ORR: 150 West to HS: 43	998/902
	All to SRS	644	SRS to ORR: 161/65	East to ORR: 150 West to HS: 43	998/902
	All to INEL	644	INEL to HS: 161/65	East to ORR: 150 West to HS: 43	998/902

[a] *Truck/Rail shipments, assuming that the truck casks used for intersite shipments are capable due to consolidation of carrying 4 times as much fuel, and rail casks 10 times as much fuel as the shipping cask received from the foreign research reactor.*

INEL = Idaho National Engineering Laboratory; ORR = Oak Ridge Reservation; SRS = Savannah River Site; NTS = Nevada Test Site; HS = Hanford Site

number of shipments for each site pair is shown in Table E-2. The number of intersite shipments is based on a 4-cask-to-1 conversion if trucks were used, and a 10-cask-to-1 conversion if trains were used, as explained in the previous section.

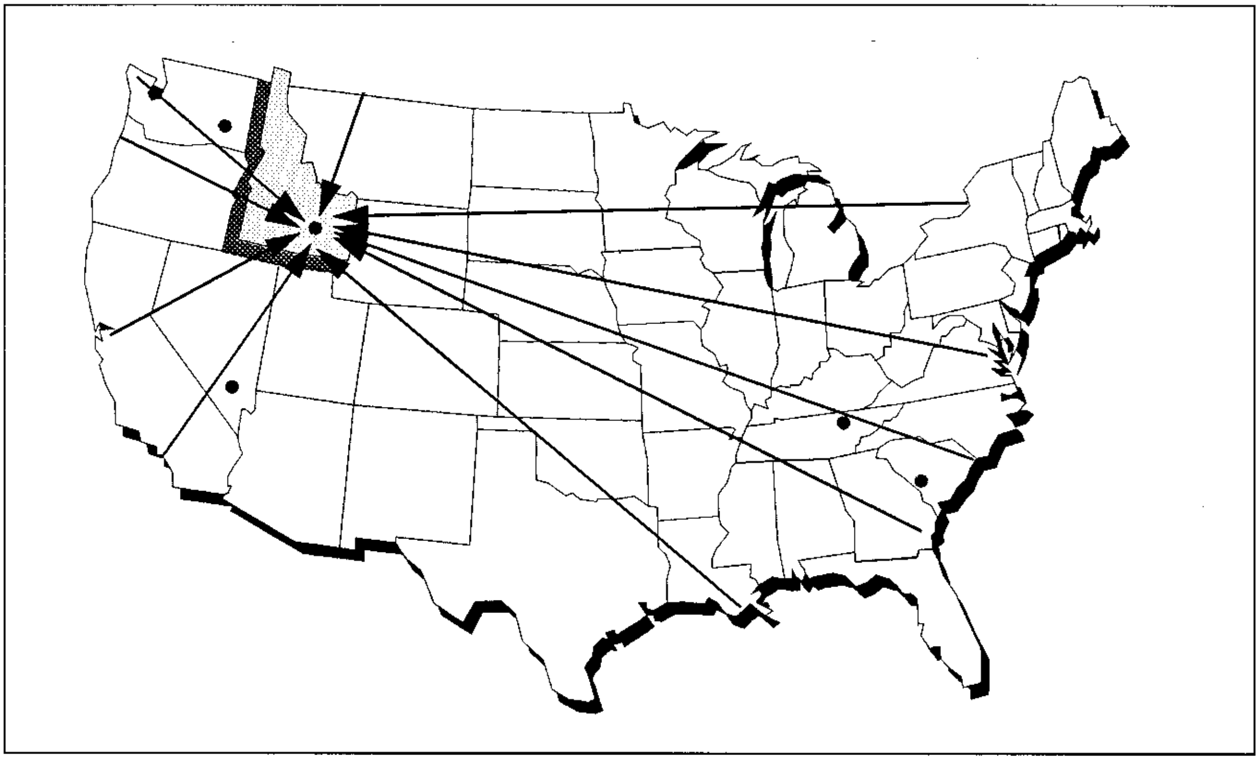

Figure E-8 Centralization to Idaho National Engineering Laboratory

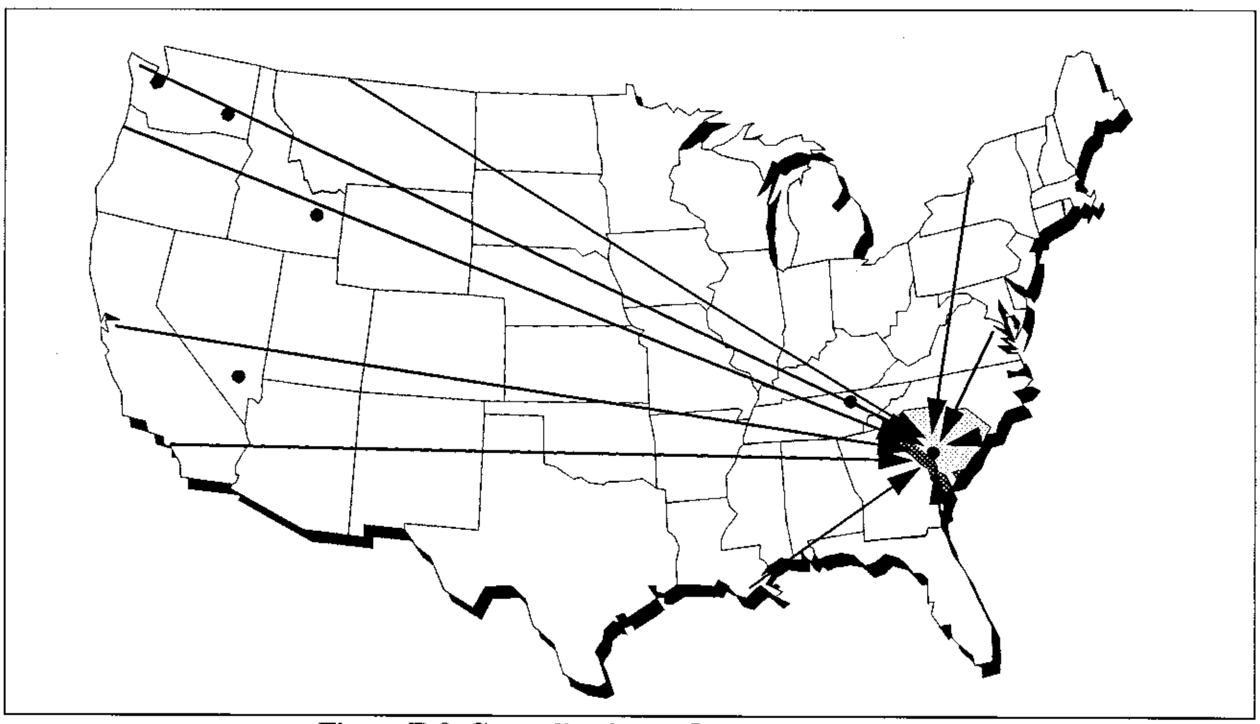

Figure E-9 Centralization to Savannah River Site

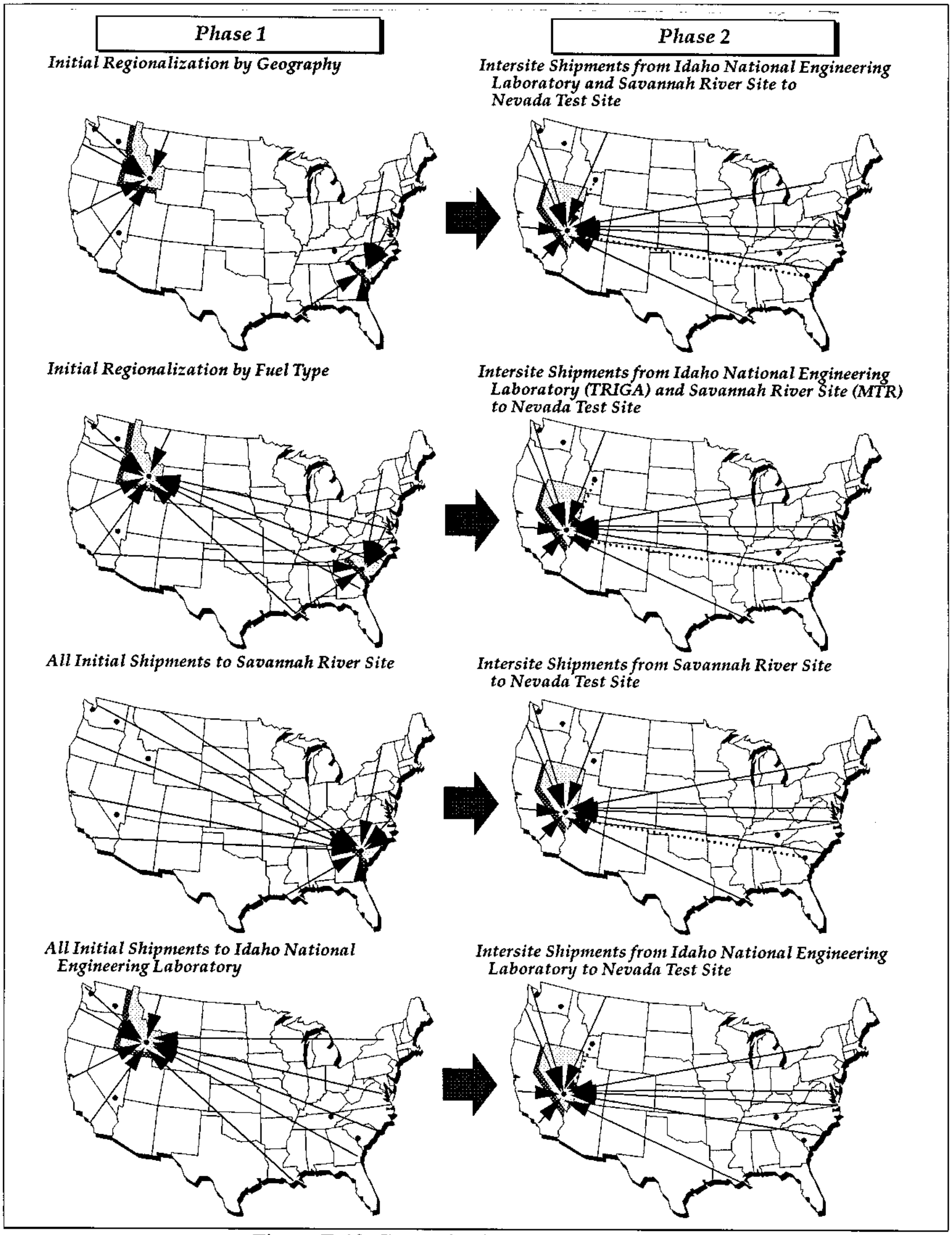

Figure E-10 Centralization to Nevada Test Site

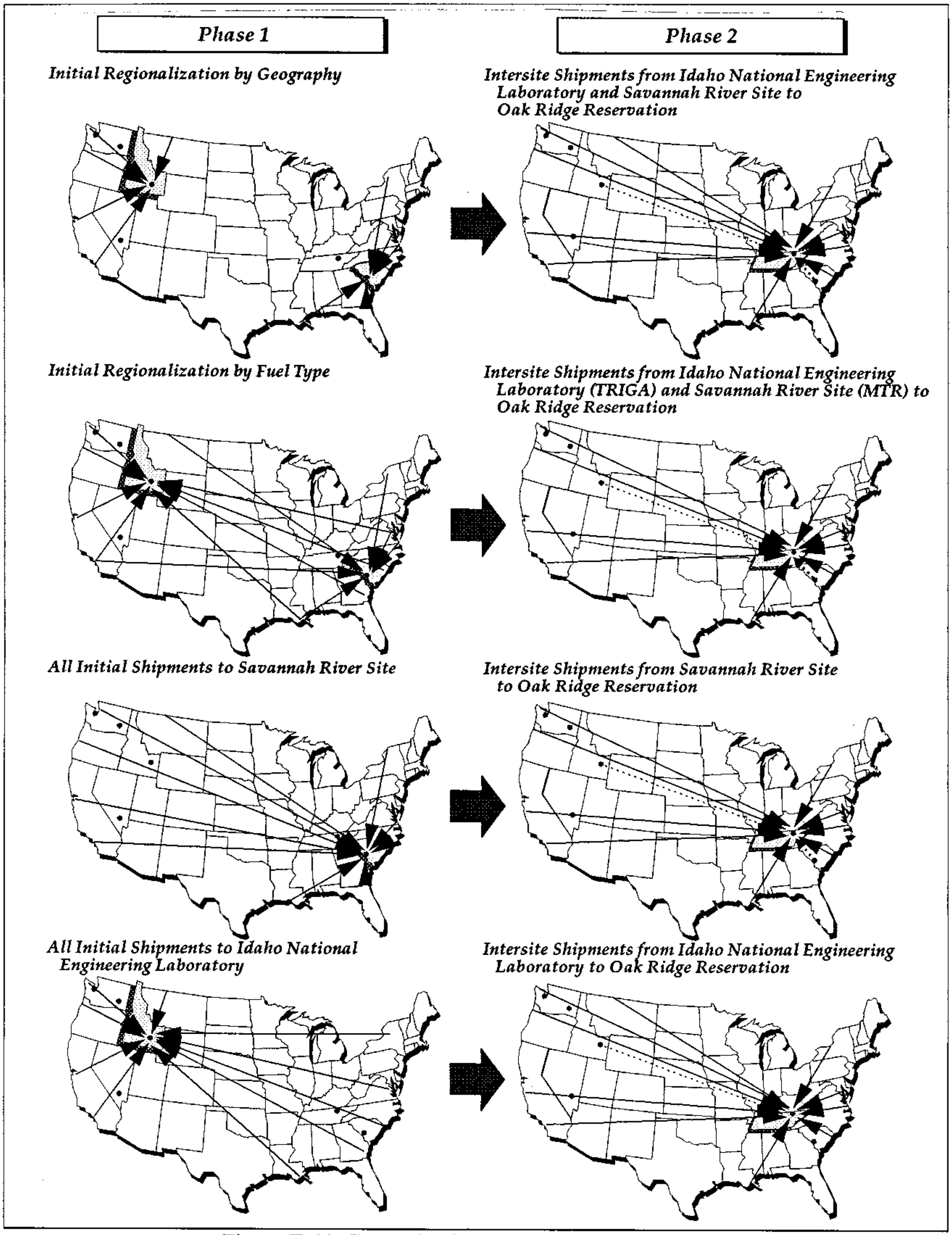

Figure E-11 Centralization to Oak Ridge Reservation

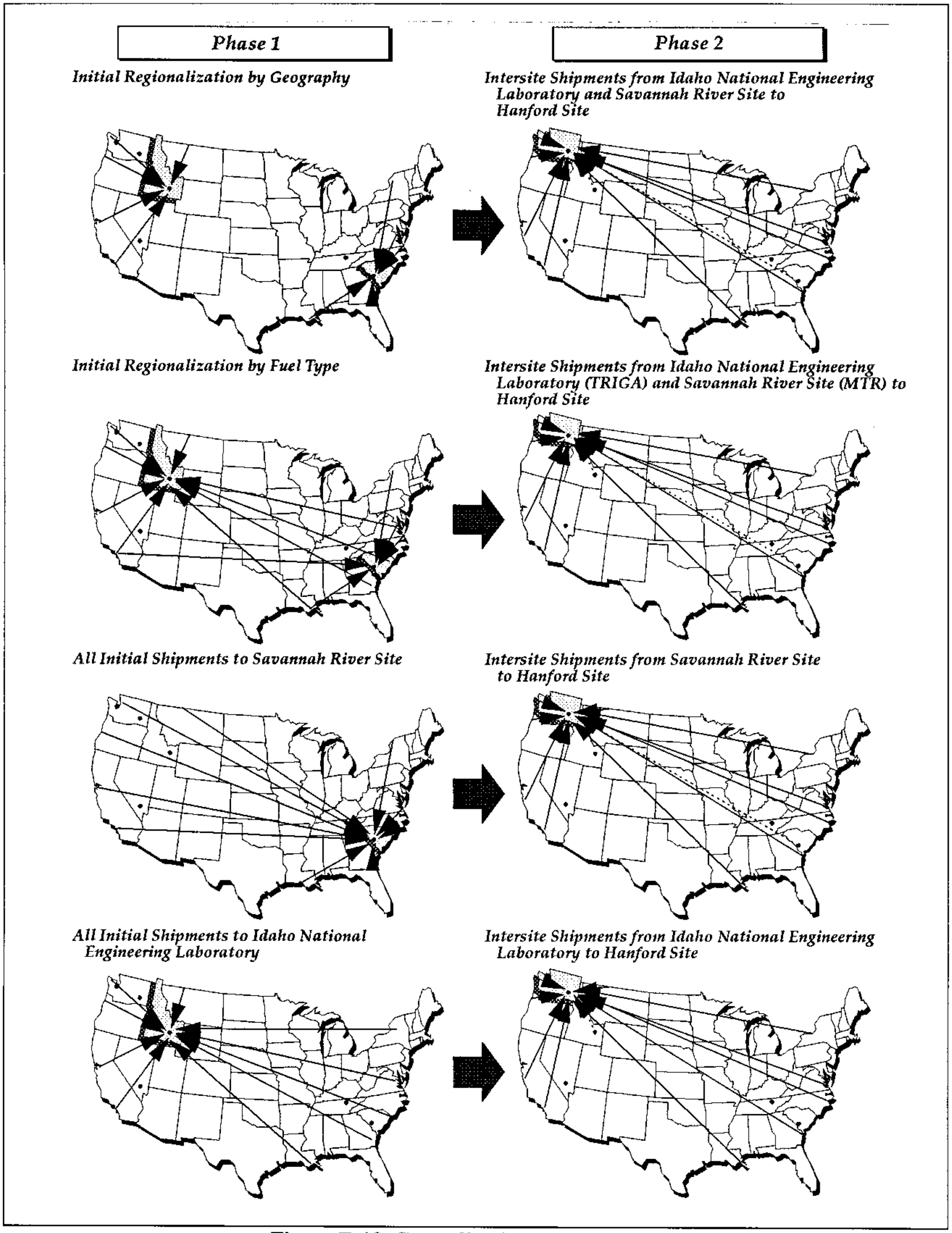

Figure E-12 Centralization to Hanford Site

Table E-2 Shipment Summary for Centralization Alternatives

Spent Nuclear Fuel Site Option	*Phase 1 Approach*	*Phase 1 Port-to-Site Shipments*	*Site-to-Site Shipments*[a]	*Phase 2 or Port-to-Final Site Shipments*	*Total Number of Shipments*
INEL	N/A - Single phase program			837	837
SRS	N/A - Single phase program			837	837
NTS	Geographic	East to SRS: 501 West to INEL: 143	From SRS: 126/51 From INEL: 36/15	From East: 150 From West: 43	999/903
	By Fuel	MTR to SRS: 520 TRIGA to INEL: 124	From SRS: 130/52 From INEL: 31/13	From East: 150 From West: 43	998/902
	All SRS	644	161/65	From East: 150 From West: 43	998/902
	All INEL	644	161/65	From East: 150 From West: 43	998/902
ORR	Geographic	East to SRS: 501 West to INEL: 143	From SRS: 126/51 From INEL: 36/15	From East: 150 From West: 43	998/903
	By Fuel	MTR to SRS: 520 TRIGA to INEL: 124	From SRS: 130/52 From INEL: 31/13	From East: 150 From West: 43	998/902
	All SRS	644	161/65	From East: 150 From West: 43	998/902
	All INEL	644	161/65	From East: 150 From West: 43	998/902
Hanford Site	Geographic	East to SRS: 501 West to INEL: 143	From SRS: 126/51 From INEL: 36/15	From East: 150 From West: 43	999/903
	By Fuel	MTR to SRS: 520 TRIGA to INEL: 124	From SRS: 130/52 From INEL: 31/13	From East: 150 From West: 43	998/902
	All SRS	644	161/65	From East: 150 From West: 43	998/902
	All INEL	644	161/65	From East: 150 From West: 43	998/902

[a] *Truck/Rail shipments assuming that the truck casks used for intersite shipments are capable of carrying 4 times as much fuel and rail casks 10 times as much fuel as the shipping cask received from the foreign research reactor due to consolidation.*

INEL = Idaho National Engineering Laboratory; ORR = Oak Ridge Reservation; SRS = Savannah River Site; NTS = Nevada Test Site; HS = Hanford Site

E.4 Truck and Rail Routing Analysis

Both rail and highway shipping capabilities are available at all potential ports of entry, and each of the five DOE sites is or could be made capable of receiving foreign research reactor spent nuclear fuel transported by rail or highway. Therefore, shipment of spent nuclear fuel will be analyzed along representative highway and railway routes for all ports and SNF&INEL Final EIS (DOE, 1995) alternatives.

As discussed above, each alternative can be defined as a set of origin and destination pairs representing shipment linkages between ports of entry and interim management sites. The calculation of the overland transportation risk for an alternative depends in part on characteristics of the transportation routes between the origin and destination sites. Regulatory routing criteria and the methods used to determine representative truck and rail routes for the transportation risk assessment are described below. In addition, the route characteristics that are important for the risk assessment are summarized.

E.4.1 Routing Regulations

Department of Transportation's public highway routing regulations are prescribed in 49 CFR Part 397. The regulations' objectives are to reduce the impacts of transporting radioactive materials, to establish consistent and uniform requirements for route selection, and to identify the role of State and local governments in the routing of radioactive materials. The regulations attempt to reduce potential hazards by avoiding populous areas and by minimizing travel times. Further, they require that the carrier of radioactive materials ensure that the vehicle is operated on routes that minimize radiological risks, and that accident rates, transit times, population density and activity, time of day, and day of week are considered in determining risk.

A shipment of a "highway route controlled quantity" of radioactive material, such as spent nuclear fuel, is required by 49 CFR 397 Subpart D to use the interstate highway system except when moving from origin to interstate or from interstate to destination, when making necessary repair or rest stops, or when emergency conditions make continued use of the interstate unsafe or impossible. Carriers are required to use interstate circumferential or bypass routes, if available, to avoid populous areas. Other "preferred highways" may be designated by any State or Tribe to replace or supplement the interstate system (DOT, 1992). Under its authority to regulate interstate transportation safety, the Department of Transportation can prohibit State and local bans and restrictions as "undue restraint of interstate commerce." State or local bans will be pre-empted if inconsistent with 49 CFR 397.

Currently, there are no Department of Transportation railroad routing regulations specific to the transportation of radioactive materials. Routes are generally fixed by the location of rail lines, and urban areas cannot be readily bypassed.

E.4.2 Determination of Representative Transportation Routes

Representative overland truck and rail routes have been determined for all pairs of origin and destination sites considered by the alternatives. The routes were selected consistent with current routing practices and all applicable routing regulations and guidelines. However, because the routes were determined for risk assessment purposes, they do not necessarily represent the actual routes that would be used to transport foreign research reactor spent nuclear fuel in the future. Specific routes cannot be identified in advance because the route would not be finalized until it had been reviewed and approved by the NRC. The selection of the actual route would be responsive to environmental and other conditions that were in effect or could reasonably be predicted at the time of shipment. Such conditions could include adverse weather conditions, truck or road conditions, bridge closures, etc. (Massey, 1994).

For both truck and rail transportation modes, the route characteristics that are important to the radiological risk assessment include the total shipment distance between each origin and destination pair and the population distribution along the route. The specific route selected determines both the total potentially exposed population and the expected frequency of transportation-related accidents. Route characteristics are summarized in Tables E-3 and E-4 for the ports of entry and management sites considered in this assessment. The ports of Philadelphia, PA; Elizabeth, NJ; and Long Beach, CA are included in the list to show the effects on overland transportation of choosing high population ports. The routes from Canada are representative for risk analysis purposes, many other routes are available for use. They are not included in the risk analysis described later in this appendix. The exposed population includes all persons living within 800 m [0.5 mile (mi)] on each side of the route. The representative routes are shown in Attachment 1 to this appendix.

Table E-3 Summary of Route Distances for Truck and Rail Modes

Route[a]	Distance km (mi)	Percentage in Zone		
		Rural	Suburban	Urban
Shipments to Hanford Site:				
From Eastern Ports				
Truck:				
Charleston, SC (NWS)	4579 (2858)	85.5	13.3	1.2
Charleston, SC (Wando Terminal)	4603 (2873)	85.3	13.4	1.3
Elizabeth, NJ	4527 (2812)	84.4	14.1	1.4
Galveston, TX	3746 (2327)	86.0	11.8	2.3
Jacksonville, FL	4708 (2924)	83.9	14.6	1.5
Newport News, VA	4682 (2908)	84.9	13.3	1.8
Norfolk, VA	4748 (2949)	84.4	13.8	1.7
Philadelphia, PA	4617 (2868)	82.9	15.6	1.5
Portsmouth, VA	4717 (2930)	84.5	13.6	1.9
Savannah, GA	4529 (2813)	84.7	13.8	1.5
MOTSU, NC	4617 (2868)	85.7	13.1	1.3
Wilmington, NC	4770 (2963)	85.3	13.5	1.1
Rail:				
Charleston, SC (NWS)	4925 (3059)	84.5	13.7	1.8
Charleston, SC (Wando Terminal)	4925 (3059)	84.5	13.7	1.8
Elizabeth, NJ	4846 (3010)	76.1	19.5	4.4
Galveston, TX	3851 (2392)	89.9	9.1	1.0
Jacksonville, FL	4941 (3069)	85.4	13.0	1.6
Newport News, VA	4972 (3088)	83.6	13.7	2.7
Norfolk, VA	5131 (3187)	83.8	13.6	2.7
Philadelphia, PA	4769 (2962)	77.1	18.6	4.3
Portsmouth, VA	5083 (3157)	84.0	13.4	2.6
Savannah, GA	4977 (3091)	85.3	13.2	1.4
MOTSU, NC	5157 (3203)	83.6	14.8	1.5
Wilmington, NC	5142 (3194)	83.7	14.7	1.5
From Western Ports				
Truck:				
Long Beach CA	1986 (1241)	80.5	14.3	5.2
NWS Concord, CA	1378 (856)	79.4	18.0	2.6
Portland, OR	407 (253)	81.5	15.3	3.3
Tacoma, WA	399 (248)	73.4	22.8	3.8
Rail:				
Long Beach, CA	2553 (1587)	85.6	8.9	5.5
NWS Concord, CA	1531 (951)	80.3	14.7	5.0
Portland, OR	385 (239)	82.1	13.4	4.5
Tacoma, WA	602 (374)	79.2	17.2	3.6
From DOE Sites/Canadian Border				
Truck:				
Alexandria Bay, NY	4456 (2768)	82.8	15.6	1.6
Idaho National Engineering Laboratory	964 (599)	91.3	7.6	1.1
Nevada Test Site	1816 (1128)	86.5	10.9	2.6
Oak Ridge Reservation	3967 (2464)	87.8	11.0	1.2
Savannah River	4390 (2727)	84.3	14.2	1.5
Sweetgrass, MT	1407 (874)	89.4	10.0	0.6
Rail:				
Alexandria Bay, NY	4634 (2878)	79.6	16.6	3.8
Idaho National Engineering Laboratory	1059 (658)	91.4	7.1	1.4

Shipments to Hanford Site:				
Route[a]	**Distance km (mi)**	**Percentage in Zone**		
		Rural	**Suburban**	**Urban**
Nevada Test Site	2096 (1302)	93.0	5.9	1.1
Oak Ridge Reservation	4188 (2601)	91.2	7.4	1.3
Savannah River	4754 (2953)	84.7	13.5	1.8
Sweetgrass, MT	976 (606)	91.7	6.8	1.6

Shipments to Idaho National Engineering Laboratory:				
Route[a]	**Distance km (mi)**	**Percentage in Zone**		
		Rural	**Suburban**	**Urban**
From Eastern Ports				
Truck:				
Charleston, SC (NWS)	3910 (2441)	84.4	14.3	1.3
Charleston, SC (Wando Terminal)	3935 (2456)	84.2	14.4	1.4
Elizabeth, NJ	3858 (2396)	82.9	15.5	1.5
Galveston, TX	3077 (1911)	84.5	13.0	2.5
Jacksonville, FL	4031 (2504)	82.5	15.9	1.5
Newport News, VA	4012 (2492)	83.5	14.6	1.9
Norfolk, VA	4073 (2530)	83.1	15.1	1.8
Philadelphia, PA	3948 (2452)	81.2	17.2	1.6
Portsmouth, VA	4048 (2514)	83.1	14.8	2.1
Savannah, GA	3861 (2398)	83.3	15.1	1.6
MOTSU, NC	3875 (2407)	85.3	13.5	1.2
Wilmington, NC	4099 (2546)	84.1	14.8	1.2
Rail:				
Charleston, SC (NWS)	4046 (2513)	82.6	15.3	2.1
Charleston, SC (Wando Terminal)	4046 (2513)	82.6	15.3	2.1
Elizabeth, NJ	3967 (2464)	72.3	22.5	5.2
Galveston, TX	2972 (1846)	88.9	10.1	1.0
Jacksonville, FL	4062 (2523)	83.7	14.6	1.7
Newport News, VA	4093 (2542)	81.5	15.4	3.1
Norfolk, VA	4252 (2641)	81.8	15.2	3.0
Philadelphia, PA	3890 (2416)	73.4	21.5	5.1
Portsmouth, VA	4204 (2611)	82.1	14.9	3.0
Savannah, GA	4097 (2545)	83.6	14.8	1.6
MOTSU, NC	4278 (2657)	81.6	16.7	1.7
Wilmington, NC	4263 (2648)	81.8	16.5	1.7
From Western Ports				
Truck:				
Long Beach, CA	1575 (979)	77.7	14.2	8.1
NWS Concord, CA	1518 (943)	85.9	11.1	3.1
Portland, OR	1188 (738)	88.6	9.8	1.7
Tacoma, WA	1312 (815)	87.0	11.4	1.6
Rail:				
Long Beach, CA	1675 (1041)	81.5	10.5	8.0
NWS Concord, CA	1473 (915)	89.0	8.7	2.4
Portland, OR	1264 (785)	92.6	5.8	1.6
Tacoma, WA	1504 (934)	88.6	9.2	2.2
From DOE Sites/Canadian Border				
Truck:				
Alexandria Bay, NY	3787 (2352)	81.0	17.2	1.7
Hanford Site	964 (599)	91.3	7.6	1.1
Nevada Test Site	1146 (712)	82.8	13.7	3.5

Shipments to Idaho National Engineering Laboratory:				
Route[a]	Distance km (mi)	Percentage in Zone		
		Rural	Suburban	Urban
Oak Ridge Reservation	3297 (2048)	86.8	12.0	1.2
Savannah River	3721 (2311)	82.8	15.6	1.6
Sweetgrass, MT	874 (543)	94.8	4.8	0.4
Rail:				
Alexandria Bay, NY	3755 (2332)	76.4	19.1	4.5
Hanford Site	1059 (658)	91.4	7.1	1.4
Nevada Test Site	1217 (756)	92.8	5.9	1.3
Oak Ridge Reservation	3309 (2055)	90.7	7.8	1.5
Savannah River	3875 (2407)	82.8	15.2	2.0
Sweetgrass, MT	1982 (1231)	93.2	5.8	1.0

Shipments to Nevada Test Site:				
Route[a]	Distance km (mi)	Percentage in Zone		
		Rural	Suburban	Urban
From Eastern Ports				
Truck:				
Charleston, SC (NWS)	3930 (2543)	84.5	14.1	1.4
Charleston, SC (Wando Terminal)	4098 (2558)	84.3	14.2	1.5
Elizabeth, NJ	4302 (2672)	80.5	17.2	2.3
Galveston ,TX	2998 (1862)	85.4	11.5	3.2
Jacksonville, FL	4197 (2607)	82.8	15.4	1.8
Newport News, VA	4178 (2595)	83.8	14.1	2.1
Norfolk, VA	4239 (2633)	83.4	14.6	2.0
Philadelphia, PA	4223 (2623)	80.4	17.4	2.2
Portsmouth, VA	4213 (2617)	83.4	14.3	2.3
Savannah, GA	4027 (2501)	83.6	14.6	1.8
MOTSU, NC	3956 (2457)	83.0	15.0	2.0
Wilmington, NC	4267 (2650)	84.3	14.3	1.4
Rail:				
Charleston, SC (NWS)	4741 (2945)	84.3	13.7	2.0
Charleston, SC (Wando Terminal)	4741 (2945)	84.3	13.7	2.0
Elizabeth, NJ	4661 (2895)	75.6	19.7	4.7
Galveston, TX	3148 (1955)	92.0	7.2	0.8
Jacksonville, FL	4758 (2955)	85.3	13.1	1.7
Newport News, VA	4787 (2973)	83.4	13.8	2.9
Norfolk, VA	4948 (3073)	83.6	13.6	2.8
Philadelphia, PA	4585 (2848)	76.6	18.8	4.6
Portsmouth, VA	4898 (3042)	83.8	13.4	2.8
Savannah, GA	4793 (2977)	85.2	13.2	1.5
MOTSU, NC	4973 (3089)	83.4	14.9	1.7
Wilmington, NC	4959 (3080)	83.5	14.8	1.7
From Western Ports				
Truck:				
Long Beach, CA	645 (401)	71.3	12.7	16.0
NWS Concord, CA	1146 (712)	81.8	11.3	6.9
Portland, OR	2045 (1270)	85.5	11.5	2.9
Tacoma, WA	2164 (1344)	84.7	12.6	2.7
Rail:				
Long Beach, CA	777 (483)	70.5	14.3	15.3
NWS Concord, CA	1369 (850)	77.8	16.7	5.6
Portland, OR	2301 (1429)	93.5	5.3	1.2

Shipments to Nevada Test Site:				
Route[a]	Distance km (mi)	Percentage in Zone		
		Rural	Suburban	Urban
Tacoma, WA	2542 (1579)	91.0	7.4	1.6
From DOE Sites/Canadian Border				
Truck:				
Alexandria Bay, NY	4217 (2619)	82.0	16.0	1.9
Hanford Site	1816 (1128)	86.5	10.9	2.6
Idaho National Engineering Laboratory	1146 (712)	82.8	13.7	3.5
Oak Ridge Reservation	3463 (2151)	86.9	11.5	1.6
Savannah River	3887 (2414)	83.1	15.1	1.8
Sweetgrass, MT	1900 (1180)	87.5	10.0	2.5
Rail:				
Alexandria Bay, NY	4448 (2763)	79.2	16.7	4.0
Hanford Site	2096 (1302)	93.0	5.9	1.1
Idaho National Engineering Laboratory	1217 (756)	92.8	5.9	1.3
Oak Ridge Reservation	4004 (2487)	91.4	7.2	1.5
Savannah River	4571 (2839)	84.5	13.5	1.9
Sweetgrass, MT	3019 (1875)	93.7	5.4	0.9

Shipments to Oak Ridge Reservation:				
Route[a]	Distance km (mi)	Percentage in Zone		
		Rural	Suburban	Urban
From Eastern Ports				
Truck:				
Charleston, SC (NWS)	644 (402)	71.6	27.6	0.8
Charleston, SC (Wando Terminal)	668 (417)	70.9	27.8	1.3
Elizabeth, NJ	1188 (738)	62.2	35.7	2.1
Galveston, TX	1550 (963)	73.3	24.6	2.1
Jacksonville, FL	913 (567)	66.8	32.0	1.3
Newport News, VA	890 (553)	69.8	27.6	2.6
Norfolk, VA	886 (550)	68.4	30.2	1.3
Philadelphia, PA	1095 (680)	64.7	31.7	3.6
Portsmouth, VA	926 (575)	68.4	28.2	3.4
Savannah, GA	723 (449)	74.3	25.0	0.6
MOTSU, NC	799 (496)	72.4	26.7	0.9
Wilmington, NC	819 (509)	72.6	26.5	0.9
Rail:				
Charleston, SC (NWS)	935 (581)	65.2	33.3	1.5
Charleston, SC (Wando Terminal)	935 (581)	65.2	33.3	1.5
Elizabeth, NJ	1264 (785)	44.7	43.2	12.2
Galveston, TX	1695 (1053)	70.5	26.2	3.3
Jacksonville, FL	910 (565)	65.7	31.9	2.4
Newport News, VA	1230 (764)	59.2	38.7	2.0
Norfolk, VA	1109 (689)	62.2	36.3	1.6
Philadelphia, PA	1129 (701)	48.6	43.0	8.4
Portsmouth, VA	1061 (659)	62.3	36.4	1.3
Savannah, GA	945 (587)	66.2	32.1	1.7
MOTSU, NC	873 (542)	61.5	37.1	1.5
Wilmington, NC	857 (532)	61.7	36.8	1.5
From Western Ports				
Truck:				
Long Beach, CA	3614 (2246)	85.0	11.0	3.8
NWS Concord, CA	4117 (2557)	86.3	10.9	2.8

Shipments to Oak Ridge Reservation:				
Route[a]	**Distance km (mi)**	**Percentage in Zone**		
		Rural	**Suburban**	**Urban**
Portland, OR	4200 (2609)	87.0	11.5	1.5
Tacoma, WA	4279 (2658)	88.0	11.0	1.0
Rail:				
Long Beach, CA	4302 (2674)	86.5	9.7	3.9
NWS Concord, CA	4524 (2810)	87.5	10.4	2.2
Portland, OR	4551 (2827)	85.5	12.1	2.4
Tacoma, WA	4568 (2837)	83.7	13.3	3.0
From DOE Sites/Canadian Border				
Truck:				
Alexandria Bay, NY	1492 (927)	65.9	33.5	0.7
Hanford Site	3967 (2464)	87.8	11.0	1.2
Idaho National Engineering Laboratory	3297 (2048)	86.8	12.0	1.2
Nevada Test Site	3463 (2151)	86.9	11.5	1.6
Savannah River	610 (379)	59.1	38.5	2.4
Sweetgrass, MT	1900 (1180)	87.5	10.0	2.5
Rail:				
Alexandria Bay, NY	1565 (972)	57.5	35.7	6.8
Hanford Site	4188 (2601)	91.2	7.4	1.3
Idaho National Engineering Laboratory	3309 (2055)	90.7	7.8	1.5
Nevada Test Site	4004 (2487)	91.4	7.2	1.5
Savannah River	671 (417)	68.8	29.8	1.4
Sweetgrass, MT	3375 (2096)	83.7	13.7	2.6

Shipments to Savannah River Site:				
Route[a]	**Distance km (mi)**	**Percentage in Zone**		
		Rural	**Suburban**	**Urban**
From Eastern Ports				
Truck:				
Charleston, SC (NWS)	301 (188)	72.9	26.2	0.9
Charleston, SC (Wando Terminal)	325 (203)	71.6	26.6	1.8
Elizabeth, NJ	1325 (823)	63.8	34.2	2.1
Galveston, TX	1610 (1000)	70.5	27.0	2.5
Jacksonville, FL	607 (377)	81.5	18.4	0.0
Newport News, VA	836 (519)	71.1	26.8	2.1
Norfolk, VA	802 (498)	72.8	26.2	1.0
Philadelphia, PA	1193 (741)	62.1	34.0	3.9
Portsmouth, VA	807 (501)	72.7	26.1	1.1
Savannah, GA	403 (250)	79.1	20.8	0.0
MOTSU, NC	403 (250)	82.5	17.2	0.3
Wilmington, NC	499 (310)	75.5	24.0	0.5
Rail:				
Charleston, SC (NWS)	225 (140)	83.9	13.6	2.5
Charleston, SC (Wando Terminal)	225 (140)	83.9	13.6	2.5
Elizabeth, NJ	1404 (872)	56.2	33.0	10.8
Galveston, TX	1890 (1174)	69.6	26.2	4.2
Jacksonville, FL	417 (259)	83.7	13.7	2.6
Newport News, VA	972 (604)	69.1	28.7	2.2
Norfolk, VA	852 (529)	74.3	24.1	1.6
Philadelphia, PA	1270 (789)	60.9	31.8	7.2
Portsmouth, VA	803 (499)	75.2	23.5	1.3
Savannah, GA	184 (114)	87.9	10.9	1.2

Shipments to Savannah River Site:				
		Percentage in Zone		
Route[a]	*Distance km (mi)*	*Rural*	*Suburban*	*Urban*
MOTSU, NC	615 (382)	77.9	20.5	1.6
Wilmington, NC	601 (373)	78.7	19.7	1.6
From Western Ports				
Truck:				
Long Beach, CA	3931 (2443)	78.8	18.0	3.3
NWS Concord, CA	4482 (2784)	79.4	17.2	3.3
Portland, OR	4635 (2879)	83.9	14.4	1.7
Tacoma, WA	4719 (2931)	84.8	13.9	1.3
Rail:				
Long Beach, CA	5212 (3239)	80.9	15.3	3.7
NWS Concord, CA	5123 (3182)	80.0	16.4	3.6
Portland, OR	5078 (3154)	82.0	15.4	2.6
Tacoma, WA	5096 (3165)	80.4	16.5	3.1
From DOE Sites/Canadian Border				
Truck:				
Alexandria Bay, NY	1629 (1012)	66.8	32.4	0.8
Hanford Site	4390 (2727)	84.3	14.2	1.5
Idaho National Engineering Laboratory	3721 (2311)	82.8	15.6	1.6
Nevada Test Site	3887 (2414)	83.1	15.1	1.8
Oak Ridge Reservation	610 (379)	59.1	38.5	2.4
Sweetgrass, MT	4147 (2576)	85.2	13.6	1.3
Rail:				
Alexandria Bay, NY	2062 (1281)	53.8	35.5	10.7
Hanford Site	4754 (2953)	84.7	13.5	1.8
Idaho National Engineering Laboratory	3875 (2407)	82.8	15.2	2.0
Nevada Test Site	4571 (2839)	84.5	13.5	1.9
Oak Ridge Reservation	671 (417)	68.8	29.8	1.4
Sweetgrass, MT	3903 (2424)	79.4	17.8	2.8

[a] *Route characteristics were generated using the routing models HIGHWAY (Johnson et al., 1993a) and INTERLINE (Johnson et al., 1993b) for truck and rail modes, respectively.*

Table E-4 Summary of the Population Distributions Along Routes for Truck and Rail Modes

Shipments to Hanford Site:				
	Number of	*Average Persons/km²*		
Route[a]	*Affected Persons*[b]	*Rural*	*Suburban*	*Urban*
From Eastern Ports				
Truck:				
Charleston, SC (NWS)	550,000	7.0	342.5	2149.1
Charleston, SC (Wando Terminal)	569,000	7.0	346.1	2158.6
Elizabeth, NJ	585,000	7.8	318.3	2233.1
Galveston, TX	575,000	4.9	401.5	2139.5
Jacksonville, FL	643,000	7.1	338.6	2180.5
Newport News, VA	677,000	7.5	356.9	2254.3
Norfolk, VA	694,000	7.6	362.0	2219.3
Philadelphia, PA	622,000	7.4	317.4	2079.3
Portsmouth, VA	718,000	7.5	364.3	2243.7
Savannah, GA	602,000	6.8	344.2	2205.1
MOTSU, NC	548,000	7.6	332.1	2146.8

Shipments to Hanford Site:				
Route[a]	Number of Affected Persons[b]	Average Persons/km^2		
		Rural	Suburban	Urban
Wilmington, NC	556,000	7.5	330.0	2149.9
Rail:				
Charleston, SC (NWS)	731,000	6.9	354.6	2296.8
Charleston, SC (Wando Terminal)	731,000	6.9	354.6	2296.8
Elizabeth, NJ	1,380,000	7.2	355.0	2506.4
Galveston, TX	347,000	4.8	374.8	2034.6
Jacksonville, FL	657,000	6.9	343.6	2272.5
Newport News, VA	936,000	7.5	329.1	2623.1
Norfolk, VA	960,000	7.6	338.8	2592.7
Philadelphia, PA	1,350,000	7.1	358.5	2567.1
Portsmouth, VA	934,000	7.6	334.2	2608.4
Savannah, GA	641,000	7.0	343.1	2244.5
MOTSU, NC	739,000	7.7	346.1	2288.1
Wilmington, NC	736,000	7.7	346.7	2288.1
From Western Ports				
Truck:				
Long Beach, CA	617,000	7.9	381.0	2693.6
NWS Concord, CA	263,000	9.3	335.1	2159.0
Portland, OR	85,700	6.3	413.3	2088.6
Tacoma, WA	98,600	7.7	321.9	2120.5
Rail:				
Long Beach, CA	783,000	3.6	471.4	2781.1
NWS Concord, CA	419,000	7.0	368.7	2363.7
Portland, OR	99,500	6.1	450.0	2294.4
Tacoma, WA	136,000	10.6	355.9	2161.1
From DOE Sites/Canadian Border				
Truck:				
Alexandria Bay, NY	612,000	7.7	300.4	2211.8
Idaho National Engineering Laboratory	82,800	5.5	363.0	2034.6
Nevada Test Site	305,000	4.1	447.3	2176.8
Oak Ridge Reservation	429,000	6.0	351.1	2207.3
Savannah River	599,000	6.7	354.7	2198.1
Sweetgrass, MT	106,000	4.5	314.4	2152.3
Rail:				
Alexandria Bay, NY	1,170,000	7.0	360.2	2584.5
Idaho National Engineering Laboratory	95,400	4.2	373.6	1935.8
Nevada Test Site	157,000	3.5	402.3	1980.5
Oak Ridge Reservation	410,000	6.7	375.7	2220.3
Savannah River	690,000	6.8	355.8	2267.6
Sweetgrass, MT	92,400	4.1	394.4	1979.9

Shipments to Idaho National Engineering Laboratory:				
Route[a]	Number of Affected Persons[b]	Average Persons/km^2		
		Rural	Suburban	Urban
From Eastern Ports				
Truck:				
Charleston, SC (NWS)	498,000	7.4	334.0	2157.4
Charleston, SC (Wando Terminal)	518,000	7.4	338.1	2167.2
Elizabeth, NJ	536,000	8.5	315.6	2257.0
Galveston, TX	526,000	5.1	405.8	2149.1

Shipments to Idaho National Engineering Laboratory:				
	Number of	***Average Persons/km²***		
Route[a]	***Affected Persons[b]***	***Rural***	***Suburban***	***Urban***
Jacksonville, FL	576,000	7.6	332.2	2224.8
Newport News, VA	628,000	8.0	356.8	2274.7
Norfolk, VA	631,000	8.1	362.5	2220.6
Philadelphia, PA	573,000	7.9	314.9	2084.2
Portsmouth, VA	670,000	8.0	364.7	2261.3
Savannah, GA	553,000	7.3	343.2	2224.8
MOTSU, NC	463,000	8.1	327.9	2155.2
Wilmington, NC	507,000	8.1	328.1	2166.9
Rail:				
Charleston, SC (NWS)	671,000	7.6	348.5	2332.6
Charleston, SC (Wando Terminal)	671,000	7.6	348.5	2332.6
Elizabeth, NJ	1, 320,000	8.2	350.8	2528.3
Galveston, TX	286,000	5.1	365.7	2068.7
Jacksonville, FL	597,000	7.7	336.3	2312.5
Newport News, VA	875,000	8.4	321.1	2665.7
Norfolk, VA	900,000	8.5	331.7	2632.7
Philadelphia, PA	1,290,000	8.1	354.2	2592.0
Portsmouth, VA	874,000	8.6	326.6	2650.6
Savannah, GA	580,000	7.8	335.9	2284.9
MOTSU, NC	679,000	8.7	340.2	2328.4
Wilmington, NC	675,000	8.7	340.8	2328.4
From Western Ports				
Truck:				
Long Beach, CA	692,000	3.8	487.0	2641.1
NWS Concord, CA	271,000	3.5	411.6	2181.5
Portland, OR	143,000	5.6	395.0	2082.7
Tacoma, WA	157,000	6.1	336.5	2098.8
Rail:				
Long Beach, CA	722,000	3.5	484.6	2830.1
NWS Concord, CA	198,000	4.4	337.2	2293.0
Portland, OR	116,000	4.3	330.2	2222.6
Tacoma, WA	199,000	6.1	326.5	2291.5
From DOE Sites/Canadian Border				
Truck:				
Alexandria Bay, NY	564,000	8.3	296.8	2230.8
Hanford Site	82,800	5.5	363.0	2034.6
Nevada Test Site	256,000	3.9	470.3	2201.5
Oak Ridge Reservation	380,000	6.3	350.4	2237.4
Savannah River	551,000	7.2	354.4	2217.9
Sweetgrass, MT	38,900	4.3	348.1	2057.3
Rail:				
Alexandria Bay NY	1,110,000	7.9	355.3	2614.7
Hanford Site	95,400	4.2	373.6	1935.8
Nevada Test Site	96,100	3.3	384.6	2022.2
Oak Ridge Reservation	350,000	7.5	365.3	2270.2
Savannah River	630,000	7.6	349.6	2303.3
Sweetgrass, MT	134,000	4.2	338.5	2068.1

Shipments to Nevada Test Site:				
Route[a]	Number of Affected Persons[b]	Average Persons/km^2		
		Rural	Suburban	Urban
From Eastern Ports				
Truck:				
Charleston, SC (NWS)	540,000	6.7	347.4	2179.0
Charleston, SC (Wando Terminal)	559,000	6.7	351.2	2186.6
Elizabeth, NJ	782,000	7.5	343.2	2300.4
Galveston, TX	595,000	4.1	463.8	2277.2
Jacksonville, FL	639,000	6.9	344.9	2265.9
Newport News, VA	691,000	7.3	370.6	2301.4
Norfolk, VA	694,000	7.4	375.5	2257.2
Philadelphia, PA	756,000	7.6	349.2	2199.9
Portsmouth, VA	732,000	7.3	378.0	2287.8
Savannah, GA	616,000	6.5	357.1	2265.9
MOTSU, NC	619,000	8.6	336.2	2218.3
Wilmington, NC	570,000	7.4	341.6	2229.9
Rail:				
Charleston, SC (NWS)	733,000	6.5	362.0	2314.6
Charleston, SC (Wando Terminal)	733,000	6.5	362.0	2314.6
Elizabeth, NJ	1,390,000	6.8	360.2	2511.5
Galveston, TX	231,000	4.3	374.6	2124.4
Jacksonville, FL	659,000	6.6	350.9	2294.0
Newport News, VA	938,000	7.1	335.5	2629.1
Norfolk, VA	963,000	7.3	345.5	2599.2
Philadelphia, PA	1,350,000	6.7	364.2	2571.7
Portsmouth, VA	936,000	7.3	340.8	2614.8
Savannah, GA	643,000	6.7	350.2	2268.7
MOTSU, NC	742,000	7.4	352.3	2308.6
Wilmington, NC	738,000	7.4	353.0	2308.6
From Western Ports				
Truck:				
Long Beach, CA	518,000	2.6	550.5	2817.2
NWS Concord, CA	437,000	3.8	559.2	2617.4
Portland, OR	375,000	4.3	452.0	2154.7
Tacoma, WA	379,000	4.7	409.3	2174.8
Rail:				
Long Beach, CA	628,000	3.4	522.1	2934.2
NWS Concord, CA	407,000	6.2	360.9	2313.2
Portland, OR	177,000	3.6	376.6	2183.0
Tacoma, WA	261,000	005	357.6	2251.6
From DOE Sites/Canadian Border				
Truck:				
Alexandria Bay NY	644,000	7.5	308.8	2262.5
Hanford Site	305,000	4.1	447.3	2176.8
Idaho National Engineering Laboratory	256,000	3.9	470.3	2201.5
Oak Ridge Reservation	443,000	5.5	370.8	2291.1
Savannah River	613,000	6.4	368.3	2261.8
Sweetgrass, MT	304,000	4.0	455.9	2167.2
Rail:				
Alexandria Bay NY	1,170,000	6.6	366.8	2589.6
Hanford Site	157,000	3.5	402.3	1980.5

Shipments to Nevada Test Site:				
Route[a]	**Number of Affected Persons[b]**	**Average Persons/km^2**		
		Rural	**Suburban**	**Urban**
Idaho National Engineering Laboratory	96,100	3.3	384.6	2022.2
Oak Ridge Reservation	413,000	6.3	394.1	2252.1
Savannah River	692,000	6.4	363.7	2287.5
Sweetgrass, MT	196,000	3.7	370.8	2067.5

Shipments to Oak Ridge Reservation:				
Route[a]	**Number of Affected Persons[b]**	**Average Persons/km^2**		
		Rural	**Suburban**	**Urban**
From Eastern Ports				
Truck:				
Charleston, SC (NWS)	108,000	15.0	297.5	1842.7
Charleston, SC (Wando Terminal)	127,000	14.7	311.5	2027.0
Elizabeth, NJ	290,000	19.9	273.2	2343.1
Galveston, TX	337,000	13.5	330.3	2358.5
Jacksonville, FL	175,000	15.3	266.0	2322.6
Newport News, VA	209,000	18.5	286.8	2316.6
Norfolk, VA	174,000	17.6	292.1	2073.3
Philadelphia, PA	335,000	18.8	335.1	2215.7
Portsmouth, VA	251,000	18.2	309.4	2270.2
Savannah, GA	101,000	14.1	274.1	1764.7
MOTSU, NC	128,000	17.6	283.4	1854.5
Wilmington, NC	128,000	16.7	280.4	1764.7
Rail:				
Charleston, SC (NWS)	194,000	17.4	272.6	2202.7
Charleston, SC (Wando Terminal)	194,000	17.4	272.6	2202.7
Elizabeth, NJ	949,000	17.1	353.3	2694.7
Galveston, TX	471,000	13.4	360.1	2306.2
Jacksonville, FL	235,000	11.6	335.9	2233.3
Newport News, VA	305,000	16.8	277.3	2175.5
Norfolk, VA	241,000	17.3	270.6	2077.6
Philadelphia, PA	649,000	16.9	333.2	2653.3
Portsmouth, VA	215,000	17.8	259.8	2075.0
Savannah, GA	218,000	12.1	335.1	2090.0
MOTSU, NC	186,000	17.7	263.7	2038.3
Wilmington, NC	183,000	17.8	263.3	2038.3
From Western Ports				
Truck:				
Long Beach, CA	823,000	6.2	380.8	2607.0
NWS Concord, CA	742,000	6.0	401.1	2426.5
Portland, OR	519,000	6.0	367.2	2195.4
Tacoma, WA	431,000	6.2	343.7	2213.8
Rail:				
Long Beach, CA	995,000	6.6	398.5	2736.4
NWS Concord, CA	664,000	6.9	379.3	2317.2
Portland, OR	765,000	7.6	393.4	2272.1
Tacoma, WA	919,000	7.7	407.7	2330.2
From DOE Sites/Canadian Border				
Truck:				
Alexandria Bay, NY	257,000	19.9	258.2	1896.7
Hanford Site	429,000	6.0	351.0	2207.3

Shipments to Oak Ridge Reservation:				
Route[a]	Number of Affected Persons[b]	Average Persons/km^2		
		Rural	Suburban	Urban
Idaho National Engineering Laboratory	380,000	6.3	350.0	2237.4
Nevada Test Site	443,000	5.5	371.0	2291.1
Savannah River	175,000	17	318.0	2244.1
Sweetgrass, MT	346,000	6.3	336.3	2180.9
Rail:				
Alexandria Bay NY	752,000	18.2	378.0	2443.0
Hanford Site	416,000	6.7	376.0	2220.3
Idaho National Engineering Laboratory	350,000	7.5	365.0	2270.2
Nevada Test Site	413,000	6.3	394.0	2252.1
Savannah River	132,000	15.2	289.0	2164.4
Sweetgrass, MT	627,000	8.7	395.5	2256.5

Shipments to Savannah River Site:				
Route[a]	Number of Affected Persons[b]	Average Person/km^2		
		Rural	Suburban	Urban
From Eastern Ports				
Truck:				
Charleston, SC (NWS)	46,200	16.3	275.0	1764.7
Charleston, SC (Wando Terminal)	65,700	15.6	306.1	2077.9
Elizabeth, NJ	316,000	17.6	277.6	2377.5
Galveston, TX	430,000	12.7	359.1	2254.1
Jacksonville, FL	46,900	13.2	211.4	1764.7
Newport News, VA	181,000	16.2	302.9	2281.5
Norfolk, VA	131,000	16.4	283.9	2007.9
Philadelphia, PA	397,000	16.5	348.5	2228.9
Portsmouth, VA	135,000	16.3	281.8	2033.1
Savannah, GA	37,300	13.6	233.4	1764.7
MOTSU, NC	34,200	15.0	213.0	1925.6
Wilmington, NC	64,700	17.7	256.7	1764.7
Rail:				
Charleston, SC (NWS)	41,200	6.8	328.6	2735.5
Charleston, SC (Wando Terminal)	41,200	6.8	328.6	2735.5
Elizabeth, NJ	903,000	14.2	353.0	2726.4
Galveston, TX	609,000	11.9	394.0	2330.3
Jacksonville, FL	72,200	10.6	290.3	2466.3
Newport News, VA	218,000	13.2	285.6	2444.8
Norfolk, VA	153,000	13.5	275.3	2469.8
Philadelphia, PA	603,000	14.0	328.8	2704.1
Portsmouth, VA	128,000	13.9	253.7	2615.8
Savannah, GA	21,300	9.6	309.0	2707.8
MOTSU, NC	99,000	12.7	260.9	2580.4
Wilmington, NC	95,500	12.8	259.6	2580.4
From Western Ports				
Truck:				
Long Beach, CA	714,000	7.5	369.4	2905.8
NWS Concord, CA	1,040,000	7.3	378.5	2381.7
Portland, OR	686,000	6.7	365.2	2188.9
Tacoma, WA	601,000	6.8	349.2	2202.0
Rail:				
Long Beach, CA	1,280,000	6.9	359.9	2653.0

Shipments to Savannah River Site:				
Route[a]	***Number of Affected Persons***[b]	***Average Person/km***^{2}		
		Rural	***Suburban***	***Urban***
NWS Concord, CA	1,210,000	7.1	381.6	2369.0
Portland, OR	950,000	7.5	369.0	2246.2
Tacoma, WA	1,100,000	7.5	381.0	2300.7
From DOE Sites/Canadian Border				
Truck:				
Alexandria, Bay NY	284,000	18.0	262.7	2072.4
Hanford Site	599,000	6.7	354.7	2198.1
Idaho National Engineering Laboratory	551,000	7.2	354.4	2217.9
Nevada Test Site	613,000	6.4	368.3	2261.8
Oak Ridge Reservation	175,000	17.0	317.7	2244.1
Sweetgrass, MT	513,000	7.1	344.0	2175.8
Rail:				
Alexandria Bay, NY	1,340,000	14.8	333.1	2756.8
Hanford Site	690,000	6.8	355.8	2267.6
Idaho National Engineering Laboratory	630,000	7.6	349.6	2303.3
Nevada Test Site	692,000	6.4	363.7	2287.5
Oak Ridge Reservation	132,000	15.2	289.2	2164.4
Sweetgrass, MT	812,000	8.4	367.3	2228.5

[a] *Route characteristics were generated using the routing models HIGHWAY (Johnson et al., 1993a) and INTERLINE (Johnson et al., 1993b) for truck and rail modes, respectively.*

[b] *The affected population includes all persons within 800 m (0.5 mi) of the route.*

The representative truck and rail routes were determined by using the routing models HIGHWAY (Johnson et al., 1993a) and INTERLINE (Johnson et al., 1993b), respectively. These models are described briefly below.

The HIGHWAY computer program is used for selecting highway routes for transporting radioactive materials within the United States by truck. The HIGHWAY data base is a computerized road atlas that currently describes approximately 386,400 kilometer (km) (240,000 mi) of roads. A complete description of the Interstate System and all United States highways is included in the database. In addition, most of the principal State highways and a number of local and community highways are also identified. The code is updated periodically to reflect current road conditions and has been benchmarked against reported mileages and observations of commercial truck firms.

Routes are calculated within the model by minimizing the total impedance between the origin and the destination. The impedance is basically defined as a function of distance and driving time along a particular highway segment. One of the special features of the HIGHWAY model is its ability to calculate routes that maximize the use of interstate highways. This feature allows the user to select routes for shipment of radioactive materials that conform to Department of Transportation regulations, specifically 49 CFR 397 Subpart D. The population densities along a route are derived from 1990 U.S. Bureau of the Census data. Rural, suburban, and urban areas are characterized according to the following breakdown: rural population densities range from 0 to 54 persons per km^2 (0 to 139 persons per mi^2); the suburban range is 55 to 1,284 persons per km^2 (140 to 3,326 persons per mi^2); and urban is taken as all population densities greater than 1,284 persons per km^2 (3,326 persons per mi^2).

The INTERLINE computer program is designed to simulate routing of the United States rail system. The INTERLINE database consists of 94 separate subnetworks and represents various competing rail companies in the United States. The database used by INTERLINE was originally based on Federal Railroad Administration data and reflected the United States railroad system in 1974. The data base has since been expanded and modified over the past 2 decades. The code is updated periodically to reflect current track conditions and has been benchmarked against reported mileages and observations of commercial rail firms.

The INTERLINE model uses a shortest-route algorithm that finds the minimum impedance path within an individual subnetwork. A separate routine is used to find paths along the subnetworks. The routes selected for this study used the standard assumptions in the INTERLINE model that simulate the selection process that railroads would use to direct shipments of spent nuclear fuel. The population densities along a route are derived from 1990 U.S. Bureau of the Census data. Rural, suburban, and urban areas are characterized according to the following breakdown: rural population densities range from 0 to 54 persons per km^2 (0 to 139 persons per mi^2); the suburban range is 55 to 1,284 persons per km^2 (140 to 3,326 persons per mi^2); and urban is taken as all population densities greater than 1,284 persons per km^2 (3,326 persons per mi^2).

E.5 Methods for Calculating Transportation Risks

The overland transportation risk assessment approach is summarized in Figure E-13. The first step in the ground transportation analysis was to determine the incident-free and accident risk factors, on a per-shipment basis, for transportation of the various types of spent nuclear fuel. Risk factors, as any risk estimate, are the product of the probability of exposure and the magnitude of the exposure. Accident risk factors were calculated for radiological and nonradiological traffic accidents. The probabilities, which are much lower than one, and the magnitudes of exposure were multiplied, yielding very low risk numbers. Incident-free risk factors were calculated for crew and public exposure to radiation emanating from the cask and public exposure to the chemical toxicity of the transportation vehicle exhaust. The probability of incident-free exposure is unity (one).

Radiological risk factors are expressed in units of rem. Later in the analysis, they will be multiplied by International Commission on Radiation Protection Publication 60 (ICRP, 1991) conversion factors and estimated numbers of shipments (see Section E.7.1) to give risk estimates in units of LCFs. The vehicle emission risk factors are calculated in latent mortalities, and the vehicle accident risk factors are calculated in mortalities. The nonradiological risk factors will be multiplied by the number of shipments.

For each alternative, risks were assessed for both incident-free transportation and accident conditions. For the incident-free assessment, risks were calculated for both collective populations of potentially exposed individuals and for MEIs. The accident assessment consists of two components: 1) a probabilistic accident risk assessment that considers the probabilities and consequences of a range of possible transportation accident environments, including low-probability accidents that have high consequences and high-probability accidents that have low consequences; and 2) an accident consequence assessment that considers only the consequences of the most severe transportation accidents postulated.

The RADTRAN 4 computer code (Neuhauser and Kanipe, 1993) is used for the incident-free and accident risk assessments to estimate the impacts to collective populations. RADTRAN 4 was developed by Sandia National Laboratories to calculate population risk associated with the transportation of radioactive materials by a variety of modes, including truck, rail, air, ship, and barge.

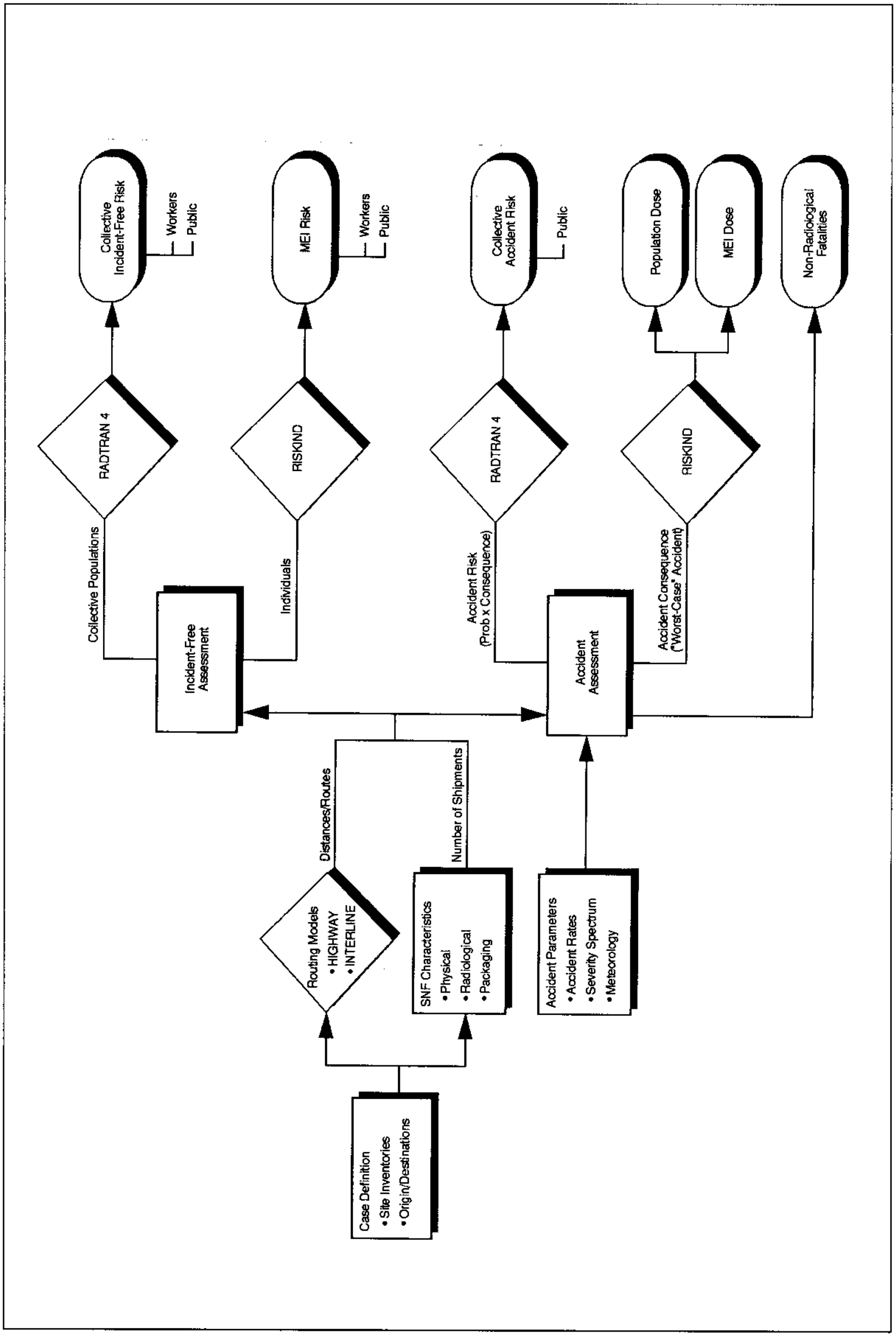

Figure E-13 Summary of the Assessment Approach for the Overland Transportation Risk Assessment

The RADTRAN 4 population risk calculations take into account both the consequences and probabilities of potential exposure events. The collective population risk is a measure of the total radiological risk posed to society as a whole by the alternative being considered. As such, the collective population risk is used as the primary means of comparing the various alternatives.

The RISKIND computer code (Yuan et al., 1993) is used to estimate the incident-free doses to MEIs and for estimating impacts for the accident consequence assessment. The RISKIND computer code was developed for DOE's Office of Civilian Radioactive Waste Management to analyze the exposure of individuals during the incident-free transportation of spent nuclear fuel. In addition, the RISKIND code was designed to allow a detailed assessment of the consequences to individuals and population subgroups from severe spent nuclear fuel transportation accidents under various environmental settings.

The RISKIND calculations were conducted to supplement the collective risk results calculated with RADTRAN 4. Whereas the collective risk results provide a measure of the overall risks of each alternative, the RISKIND calculations are meant to address areas of specific concern to individuals and population subgroups. Essentially, the RISKIND analyses are meant to address "What if" questions, such as, "What if I live next to a site access road?" or "What if an accident happens near my town?"

E.5.1 Incident-Free Risk Assessment Methodology

Radiological dose during normal, incident-free transportation of spent nuclear fuel results from exposure to the external radiation field that surrounds the shipping containers. The dose is a function of the number of people exposed, their proximity to the containers, their length of time of exposure, and the intensity of the radiation field surrounding the containers.

Collective Population Risk: The consequences (dose) during incident-free conditions are expected to occur, therefore, the probability of incident-free consequences is taken to be unity (one) in the RADTRAN 4 code. The radiological risk associated with incident-free transportation conditions results from the potential exposure of people to external radiation in the vicinity of loaded shipments. The maximum allowable external dose rates for exclusive-use shipments were presented in Section E.3.

For incident-free transportation conditions, the RADTRAN 4 computer code considers all major groups of potentially exposed persons. The RADTRAN 4 risk calculations for incident-free highway and rail transportation include exposures of the following population groups:

- Persons along the route (off-link population): Collective doses are calculated for all persons living or working within 800 m (0.5 mi) on each side of a transportation route. The total number of persons within the 1.6 km (1 mi) corridor is calculated separately for each route considered in the assessment.

- Persons sharing the route (on-link population): Collective doses are calculated for persons in all vehicles sharing the transportation route. This group would include persons traveling in the same or opposite direction as the shipment, as well as persons in vehicles passing the shipment.

- Persons at stops: Collective doses are calculated for people who could be exposed while a shipment was stopped en route. For truck transportation, this would include refueling stops, food stops, and rest stops. For rail transportation, stops are assumed to occur for classification purposes.

- Crew Members: Collective doses are calculated for truck and rail transportation crew members.

The doses calculated for the first three population groups are added together to yield the collective dose to the general public. The dose calculated for the fourth group represents the collective dose to workers. The RADTRAN 4 incident-free dose models are not intended to be used for estimating specific risks to individuals.

The RADTRAN 4 incident-free dose calculations are based on expressing the dose rate as a function of distance from a point source (Neuhauser and Kanipe, 1993). Associated with the calculation of incident-free doses for each exposed population group are parameters such as the radiation field strength, source-receptor distance, exposure time, vehicle speed, stop time, traffic density, and route characteristics such as population density. The RADTRAN 4 code user's manual contains derivations of the equations and descriptions of these parameters (Neuhauser and Kanipe, 1993). The values for many of the most important parameters are presented in Section E.6.

The collective incident-free risks are calculated for each specific alternative as follows. Each alternative is first defined as a set of origin and destination pairs. Representative highway and rail routes are determined for each unique pair as described in Section E.4. For each pair, RADTRAN 4 is used to calculate the collective risks to workers and the public for a single shipment based on representative radiological and physical properties of the spent nuclear fuel. These estimates for a single shipment are referred to as per-shipment risk factors. The number of shipments transported across each linkage is then determined for both truck and rail modes. The collective risks for an alternative are calculated by multiplying the number of shipments by the appropriate per-shipment risk factor.

MEI Risk: In addition to the incident-free collective population risk assessment, the risk to MEIs has been estimated for a number of hypothetical exposure events using RISKIND. The receptors include transportation crew members, inspectors, and members of the public exposed during traffic delays, while working at a service station, or living near a port of entry or DOE site.

The dose to each MEI considered is calculated with RISKIND for a given distance, duration, and frequency of exposure specific to that receptor. The distances and durations of exposure are similar to those given in previous transportation assessments and are presented in Section E.6. The exposure scenarios are not meant to be exhaustive, but were selected to provide a realistic range of potential exposure situations.

The RISKIND external dose model considers direct external exposure and exposure from radiation scattered from the ground and air. RISKIND is used to calculate the dose as a function of distance (mrem per hr for stationary exposures and mrem per event for moving shipments) from a spent nuclear fuel shipment based on the dimensions of the shipment. The code models the shipment as a cylindrical volume source; and the calculated dose includes contributions from buildup, cloudshine, and groundshine. The dose rates calculated by using RISKIND have been compared with output from existing shielding codes. The RISKIND code has been found to produce realistic but conservative results. As a conservative measure, potential shielding between the cask and the receptor is not considered.

Nonradiological Risk (Vehicle Related): Vehicle-related health risks resulting from incident-free transport may be associated with the generation of air pollutants by transport vehicles during spent nuclear fuel shipment, and are independent of the radioactive nature of the shipment. The health end point assessed under incident-free transport conditions is the excess latent mortality due to inhalation of vehicle exhaust emissions. Risk factors for pollutant inhalation in terms of latent mortality have been generated (Rao et al., 1982). These risks are $1x10^{-7}$ mortality per km ($1.6x10^{-7}$ per mi) and $1.3x10^{-7}$ mortality per km ($2.1x10^{-7}$ per mi) of truck and rail travel in urban areas, respectively. The risk factors are based on regression analyses of the effects of sulfur dioxide and particulate releases from diesel exhaust on mortality rates. Excess latent mortalities are assumed to be equivalent to LCF. Vehicle-related risks from incident-free transportation are calculated for each case by multiplying the total distance traveled in urban areas by the appropriate risk factor. Similar data are not available for rural and suburban areas.

Risks are summed over the entire route and over all shipments for each spent nuclear fuel case. This method has been used in several reports to calculate risks from incident-free transport. Lack of information for rural and suburban areas is an obvious data gap, although the risk factor would presumably be lower than for urban areas because of lower total emissions from all sources and lower population densities in rural and suburban areas.

E.5.2 Accident Assessment Methodology

The offsite spent nuclear fuel transportation accident analysis considers the impacts of accidents during the transportation of spent nuclear fuel by truck or rail. Under accident conditions, impacts to human health and the environment could result from the release and dispersal of radioactive material. Because of the rigorous design specifications for spent nuclear fuel shipping casks, the NRC has estimated that casks will withstand 99.4 percent of truck or rail accidents without sustaining damage sufficient to breach the cask (Fischer et al., 1987). The 0.6 percent of accidents that could potentially breach the cask are represented by a spectrum of accident severities and radioactive material release conditions. Accident analysis methodology has been developed by the NRC for calculating the probabilities and consequences from this spectrum of unlikely accidents, but it is not possible to predict where along the shipping route such accidents might occur. To provide an assessment of spent nuclear fuel transportation accident impacts, two types of analyses were performed. First, an accident risk assessment was performed that takes into account the probabilities and consequences of a spectrum of accident severities using methodology developed by the NRC (Fischer et al., 1987). The accident risk assessment used route-specific information for accident rates and population densities. For the spectrum of accidents considered in the analysis, accident consequences in terms of collective dose to the population within 80 km (50 mi) were multiplied by the accident probabilities to yield dose risk. Second, to represent the maximum reasonably foreseeable impacts to individuals and populations should an accident occur, radiological consequences were calculated for an accident of maximum credible severity in each population zone. An accident is considered credible if its probability of occurrence is greater than 1×10^{-7} per yr.

Accident Risk Assessment: The risk analysis of potential accidents differs from the incident-free analysis because accident occurrences are statistical in nature. The accident risk assessment is treated probabilistically in RADTRAN 4. Accident risk is defined as the product of the accident consequence (dose) and the probability of the accident occurring. In this respect, the RADTRAN 4 code estimates the collective accident risk to populations by considering a spectrum of transportation accidents. The accident spectrum is designed to encompass a range of possible accident environments, including low-probability accidents that have high consequences and high-probability accidents that have low consequences (i.e., "fender benders"). The collective accident risk results can be directly compared with the incident-free collective risk results because they incorporate the probabilities of accident occurrences.

The RADTRAN 4 calculation of collective accident risk employs models that quantify the range of potential accident severities and the responses of transport packages (i.e., casks) to accident environments. The accident severity spectrum is divided into a number of accident severity categories. Each severity category is assigned a conditional probability of occurrence; that is, the probability that an accident will be of a particular severity if an accident occurs. The more severe the accident, the more remote the chance of such an accident. Release fractions, defined as the fraction of the material in a package that could be released in an accident, are assigned to each accident severity category based on the physical and chemical form of the spent nuclear fuel. The models take into account the transportation mode and the type of packaging being considered. The accident rates, definition of accident severity categories, and release fractions used in this analysis are discussed further in Section E.6.

For accidents involving the release of radioactive material, RADTRAN 4 assumes the material is dispersed in the environment according to standard Gaussian diffusion models. For the risk assessment, default atmospheric dispersion data were used representing an instantaneous ground-level release and a small diameter source cloud (Neuhauser and Kanipe, 1993). The calculation of collective population dose following the release and dispersal of radioactive material includes the following exposure pathways:

- external exposure to the passing radioactive cloud,
- external exposure to contaminated ground,
- internal exposure from inhalation of airborne contaminants, and
- internal exposure from the ingestion of contaminated food.

For the ingestion pathway, state-specific food transfer factors, which relate the amount of radioactive material ingested by people to the amount deposited on the ground, were derived in accordance with the methods described by NRC Guide 1.109 (NRC, 1977b). Radiation doses are calculated using standard dose conversion factors in DOE/EH-0070 (DOE, 1988a) and DOE/EH-0071 (DOE, 1988b).

The collective accident risk for each alternative is determined in a manner similar to that described for incident-free collective risks. Accident risks are first calculated for each unique origin and destination pair ("per-shipment" risk factors) and then summed over all pairs to estimate the total risk for the alternative. The accident risk assessment uses site- and spent nuclear fuel-type-specific radiological and physical characteristics, described further in Section E-6. In addition, the assessment uses route-specific population density information and accident rates derived for individual States.

Accident Consequence Assessment: The RISKIND code is used to provide a detailed assessment of the consequences of the most severe transportation accidents. Whereas the RADTRAN 4 accident risk assessment considers the entire range of accident severities and their related probabilities, the RISKIND accident consequence assessment assumes that an accident of the highest credible severity has occurred. The accident consequence assessment is intended to provide an estimate of the maximum potential impact posed by a severe transportation accident involving spent nuclear fuel.

The severe accidents considered in the consequence assessment are characterized by extreme mechanical and thermal forces. In all cases, these accidents result in a release of radioactive material to the environment. The accidents correspond to those within the highest accident severity category as described above. These accidents represent low-probability, high-consequence events. The probability of accidents of this magnitude occurring for each alternative depends on the total shipment distance. However, accidents of this severity are extremely rare in general.

RISKIND was used for the accident consequence assessment for two reasons. First, the code has the ability to model the complex atmospheric dispersion present in severe accident environments. The atmospheric dispersion is modeled as an instantaneous release using standard Gaussian puff methods. In addition, because severe accidents routinely involve fires, modeling of the potential radiological consequences takes into account physical phenomena resulting from the fire, such as buoyant plume rise. Second, RISKIND can be used to estimate the dose to MEIs in the vicinity of an accident. The location of the MEI is determined by RISKIND based on the atmospheric conditions assumed at the time of the accident and thermal characteristics of the release.

The consequences of the most severe accidents are calculated for both local populations and MEIs. The population dose includes the population within 80 km (50 mi) of the accident site. The exposure pathways considered are similar to those discussed above for the accident risk assessment. Although post-accident remedial activities (e.g., immediate evacuation of the public or cleanup of dispersed radioactive material) would reduce the consequences of an accident, these activities were not given credit in the dose calculations.

Because it is impossible to predict the exact location of a severe transportation accident, separate accident consequences are calculated for accidents occurring in rural, suburban, and urban population density zones. Moreover, to address the effects of the atmospheric conditions existing at the time of an accident, two different atmospheric conditions are considered. The first case assumes neutral atmospheric conditions, and the second, stable conditions. Atmospheric conditions are discussed further in Section E.6.

Nonradiological Accident Risk Assessment: The nonradiological accident risk refers to the potential occurrence of transportation accidents that directly result in fatalities that are not related to the shipment cargo. This risk represents fatalities from mechanical causes. State-specific transportation fatality rates are used in the assessment and are discussed in Section E.6. Nonradiological accident risks are calculated for each alternative by multiplying the total distance traveled in each State by the appropriate State fatality rate. In all cases, the nonradiological accident risks are calculated using round-trip shipment distances.

E.6 Input Parameters and Assumptions

The transportation risk assessment is designed to ensure—through uniform and judicious selection of models, data, and assumptions—that relative comparisons of risk among the various alternatives are meaningful. The major input parameters and assumptions used in the transportation risk assessment are discussed below.

Appendix B lists the casks that are being considered for intersite shipments. The sizes of casks identified vary considerably. Since it is not clear what size of cask would be used for intersite shipments, and since the shipments would not begin until 2005, hypothetical cask sizes are used in this assessment. Additionally, fuel that arrives at an interim site would be physically modified, depending on the dry or wet storage option chosen. Therefore, it is assumed that if spent nuclear fuel were shipped by truck, the number of shipments would be one-quarter of the number of shipments from ports. If the spent nuclear fuel were shipped by rail, the number of shipments would be one-tenth of the number of shipments from ports.

E.6.1 Spent Nuclear Fuel Inventory and Characterization Data

For the purposes of analysis, the foreign research reactor spent nuclear fuel has been characterized into five different spent nuclear fuel categories for shipments into ports and two for shipments between DOE sites. The detailed discussion of the fuel and casks is provided in Appendix B. The curie content of fully loaded shipments is summarized in Table E-5. The approach for calculating the number of shipments from the various countries is shown in Appendix B.

Table E-5 Curie Content of Fully Loaded Shipping Casks for Representative Fuel Types

Isotopes	*Material Type*					
	BR-2	*RHF*	*TRIGA*	*NRU*	*HLW (1 yr)*	*Target*
Tritium	$8.64x10^{+1}$	$3.70x10^{+1}$	$1.31x10^{+1}$	$9.48x10^{-1}$	~ 0	~ 0
Krypton 85	$2.47x10^{+3}$	$1.07x10^{+3}$	$3.63x10^{+2}$	$2.71x10^{+3}$	~ 0	~ 0
Strontium 89	$4.08x10^{+4}$	$1.76x10^{+4}$	$2.75x10^{+3}$	$9.72x10^{+3}$	$3.07x10^{+6}$	$1.95x10^{+2}$
Strontium 90	$2.08x10^{+4}$	$8.93x10^{+3}$	$3.16x10^{+3}$	$2.32x10^{+4}$	$1.74x10^{+6}$	$1.58x10^{+2}$
Yttrium 90	$2.08x10^{+4}$	$8.93x10^{+3}$	$3.16x10^{+3}$	$2.32x10^{+4}$	$1.74x10^{+6}$	$1.58x10^{+2}$
Yttrium 91	$7.30x10^{+4}$	$3.14x10^{+4}$	$4.56x10^{+3}$	$2.02x10^{+4}$	$5.48x10^{+6}$	$3.69x10^{+2}$
Zirconium 95	$1.07x10^{+5}$	$4.63x10^{+4}$	$6.48x10^{+3}$	$3.38x10^{+4}$	$8.08x10^{+6}$	$5.67x10^{+2}$
Niobium 95	$2.20x10^{+5}$	$9.49x10^{+4}$	$1.28x10^{+4}$	$7.34x10^{+4}$	$1.65x10^{+7}$	$1.21x10^{+3}$
Ruthenium 103	$8.90x10^{+3}$	$3.77x10^{+3}$	$8.44x10^{+2}$	$1.44x10^{+3}$	$7.16x10^{+5}$	$3.57x10^{+1}$
Rhodium 103m	$8.90x10^{+3}$	$3.77x10^{+3}$	$8.44x10^{+2}$	$1.44x10^{+3}$	$7.16x10^{+5}$	$3.57x10^{+1}$
Ruthenium 106	$2.15x10^{+4}$	$9.16x10^{+3}$	$2.54x10^{+3}$	$1.84x10^{+4}$	$1.88x10^{+6}$	$1.49x10^{+2}$
Rhodium 106m	$2.15x10^{+4}$	$9.16x10^{+3}$	$2.54x10^{+3}$	$1.84x10^{+4}$	$1.88x10^{+6}$	$1.49x10^{+2}$
Tin 123	$4.27x10^{+2}$	$1.84x10^{+2}$	$2.71x10^{+1}$	$2.40x10^{+2}$	$5.84x10^{+4}$	$2.70x10^{+0}$
Antimony 125	$8.90x10^{+2}$	$3.81x10^{+2}$	$1.19x10^{+2}$	$9.12x10^{+2}$	$7.57x10^{+4}$	$6.51x10^{+0}$
Tellurium 125m	$2.12x10^{+2}$	$9.06x10^{+1}$	$2.87x10^{+1}$	$2.21x10^{+2}$	$1.81x10^{+4}$	$1.56x10^{+0}$
Tellurium 127m	$8.87x10^{+2}$	$3.82x10^{+2}$	$5.57x10^{+1}$	$4.42x10^{+2}$	$6.97x10^{+4}$	$5.39x10^{+0}$
Tellurium 129m	$1.89x10^{+2}$	$7.98x10^{+1}$	$2.31x10^{+1}$	$2.30x10^{+1}$	$1.59x10^{+4}$	$6.73x10^{-1}$
Cesium 134	$1.64x10^{+4}$	$4.00x10^{+3}$	$1.16x10^{+3}$	$3.54x10^{+4}$	$1.41x10^{+6}$	$6.12x10^{-1}$
Cesium-137	$2.06x10^{+4}$	$8.87x10^{+3}$	$3.19x10^{+3}$	$2.30x10^{+4}$	$1.74x10^{+6}$	$1.56x10^{+2}$
Cerium 141	$5.74x10^{+3}$	$2.44x10^{+3}$	$6.97x10^{+2}$	$6.65x10^{+3}$	$5.59x10^{+5}$	$2.03x10^{+1}$
Cerium 144	$3.12x10^{+5}$	$1.35x10^{+5}$	$2.55x10^{+4}$	$2.54x10^{+5}$	$2.49x10^{+7}$	$2.18x10^{+3}$
Praseodymium 144	$3.12x10^{+5}$	$1.35x10^{+5}$	$2.55x10^{+4}$	$2.54x10^{+5}$	$2.49x10^{+7}$	$2.18x10^{+3}$
Promethium 147	$4.83x10^{+4}$	$2.46x10^{+4}$	$7.02x10^{+3}$	$2.98x10^{+4}$	$3.70x10^{+6}$	$5.14x10^{+2}$
Promethium 148m	$7.56x10^{+1}$	$2.92x10^{+1}$	$4.68x10^{+1}$	$1.40x10^{+0}$	$7.13x10^{+3}$	$2.43x10^{-2}$
Europium 154	$6.20x10^{+2}$	$1.63x10^{+2}$	$4.18x10^{+1}$	$1.35x10^{+3}$	$6.24x10^{+4}$	$7.90x10^{-2}$
Europium 155	$1.30x10^{+2}$	$4.56x10^{+1}$	$2.27x10^{+1}$	$2.45x10^{+2}$	$1.29x10^{+4}$	$3.35x10^{+0}$
Uranium 234	$9.14x10^{-4}$	$3.74x10^{-4}$	$1.81x10^{-4}$	$1.57x10^{-3}$	~ 0	$6.81x10^{-6}$
Uranium 235	$1.38x10^{-2}$	$1.09x10^{-2}$	$7.91x10^{-3}$	$6.06x10^{-3}$	~ 0	$3.98x10^{-3}$
Uranium 238	$3.41x10^{-4}$	$2.06x10^{-4}$	$6.51x10^{-3}$	$2.67x10^{-5}$	~ 0	$7.22x10^{-5}$
Plutonium 238	$6.42x10^{+1}$	$1.03x10^{+1}$	$3.03x10^{+0}$	$2.70x10^{+2}$	$8.48x10^{+3}$	$1.60x10^{-4}$
Plutonium 239	$1.84x10^{+0}$	$8.89x10^{-2}$	$5.50x10^{-1}$	$3.32x10^{-1}$	$4.05x10^{+2}$	$2.95x10^{-2}$
Plutonium 240	$1.20x10^{+0}$	$4.21x10^{-1}$	$2.09x10^{+0}$	$2.42x10^{-1}$	$3.26x10^{+2}$	$6.85x10^{-4}$
Plutonium 241	$2.84x10^{+2}$	$6.77x10^{+1}$	$2.13x10^{+2}$	$7.09x10^{+1}$	$7.84x10^{+4}$	$7.09x10^{-3}$
Americium 241	$3.96x10^{-1}$	$9.67x10^{-2}$	$4.07x10^{-1}$	$1.24x10^{-1}$	$9.84x10^{+1}$	$1.16x10^{-5}$
Americium 242m	$1.05x10^{-3}$	$1.55x10^{-4}$	$9.00x10^{-3}$	$6.00x10^{-4}$	$6.70x10^{-1}$	$2.13x10^{-10}$
Americium 243	$4.33x10^{-3}$	$3.76x10^{-3}$	$4.38x10^{-4}$	$3.51x10^{-3}$	$1.44x10^{+1}$	$1.47x10^{-10}$
Curium 244	$1.33x10^{+0}$	$9.26x10^{-3}$	$7.14x10^{-3}$	$2.70x10^{-1}$	$1.22x10^{+2}$	$1.63x10^{-10}$
Curium 242	$1.75x10^{+0}$	$1.27x10^{-1}$	$5.25x10^{+0}$	$1.03x10^{+0}$	$9.91x10^{+2}$	$6.86x10^{-8}$

E.6.2 Shipment External Dose Rates

The dose and corresponding risk to populations and MEIs during incident-free transportation conditions are directly proportional to the assumed shipment external dose rate. The Federal regulations for maximum allowable external dose rates for exclusive-use shipments were presented in Section E.3.

The actual shipment dose rate is a complex function of the composition and configuration of shielding and containment materials used in the cask, the geometry of the loaded shipments, and characteristics of the spent nuclear fuel itself. Based on actual measurements of the dose rate outside real shipping casks, a realistic dose rate of 1 mrem per hr at a distance of 2 m (6.6 ft) was estimated, as described in Appendix F.

However, since individual casks would be expected to exceed this average value, the analysis assumes that all casks would be at the regulatory limits of 10 mrem per hr at 2 m (6.6 ft). In practice, external dose rates would vary from spent nuclear fuel type to spent nuclear fuel type and from shipment to shipment.

E.6.3 Accident Involvement Rates

For the calculation of accident risks, vehicle accident and fatality rates are taken from data provided in other reports (Saricks and Kvitek, 1994). For each transport mode, accident rates are generically defined as the number of accident involvements (or fatalities) in a given year per unit of travel of that mode in that same year. Therefore, the rate is a fractional value, with accident-involvement count as the numerator of the fraction and vehicular activity (total travel distance) as its denominator. Accident rates are generally determined for a multi-year period. For assessment purposes, the total number of expected accidents or fatalities is calculated by multiplying the total shipment distance for a specific case by the appropriate accident or fatality rate.

For truck transportation, the rates presented are specifically for heavy combination trucks involved in interstate commerce (Saricks and Kvitek, 1994). Heavy combination trucks are rigs composed of a separable tractor unit containing the engine and one to three freight trailers connected to each other. Heavy combination trucks are typically used for radioactive waste shipments. The truck accident rates are computed for each State based on statistics compiled by the Department of Transportation Office of Motor Carriers for 1986–1988. Saricks and Kvitek present accident involvement and fatality counts; estimated kilometers of travel by State; and the corresponding average accident involvement, fatality, and injury rates for the 3 years investigated. Fatalities are deaths (including crew members) that are attributable to the accident or that occurred at any time within 30 days thereafter.

Rail accident rates are computed and presented similarly to truck accident rates; however, the unit of haulage is considered to be the railcar (Saricks and Kvitek, 1994). The State-specific rail accident involvement and fatality rates are based on statistics compiled by the Federal Railroad Administration for 1985–1988. Rail accident rates include both main line accidents and those occurring in railyards. It is important to note that the accident rates used in this assessment were computed using the universe of all interstate heavy combination truck shipments, independent of shipment cargo. The cited report points out that shippers and carriers of radioactive material generally have a higher-than-average awareness of transport risk and prepare cargoes and drivers for such shipments accordingly (Saricks and Kvitek, 1994). This preparation should have a twofold effect of reducing component/equipment failure and mitigating the human error contribution to accident causation. These effects were not given credit in the accident assessment.

E.6.4 Cask Accident Response Characteristics

E.6.4.1 Accident Severity Categories

A generic method to characterize the potential severity of transportation accidents was first described in an NRC report commonly referred to as NUREG-0170 (NRC, 1977a). The NRC method divided the spectrum of transportation accident severities into eight categories. Subsequently, other studies have divided the same accident spectrum into 6 categories (Wilmot, 1981) and 20 categories (Fischer et al., 1987). Results from the latter study, which utilizes 20 severity categories and is commonly referred to as the "modal study," are used in this analysis.

The modal study (Fischer et al., 1987) was the result of an initiative taken by the NRC to refine more precisely the analysis presented in NUREG-0170 (NRC, 1977a) for spent nuclear fuel shipping casks. Whereas the NUREG-0170 analysis was primarily performed using best engineering judgments and presumptions concerning cask response, the modal study relies on sophisticated structural and thermal engineering analysis and a probabilistic assessment of the conditions that could be experienced in severe transportation accidents. The modal study results are based on representative spent nuclear fuel casks that were assumed to have been designed, manufactured, operated, and maintained in accordance with national codes and standards. Design parameters of the representative casks were chosen to meet the minimum test criteria specified in 10 CFR Part 71. The study is believed to provide realistic, yet conservative, results for radiological releases under transport accident conditions.

In the modal study, potential accident damage to a cask is categorized according to the magnitude of the mechanical forces (impact) and thermal forces (fire) to which a cask may be subjected during an accident. Because all accidents can be described in these terms, severity is independent of the specific accident sequence. In other words, any sequence of events that results in an accident in which a cask is subjected to forces within a certain range of values is assigned to the accident severity category associated with that range. The accident severity scheme is designed to take into account all potential foreseeable transportation accidents, including accidents with low probability but high consequences and those with high probability but low consequences.

Each severity category actually represents a set of accidents defined by a combination of mechanical and thermal forces. A conditional probability of occurrence—that is, the probability that if an accident occurs, it is of a particular severity—is assigned to each category. The cask response regions and the fractional occurrences by accident severity category are shown in Figure E-14 for truck and rail accidents. Accidents in Region (1,1) are the least severe but most frequent, whereas accidents in Region (4,5) are very severe but very infrequent. To determine the expected frequency of an accident of a given severity, the conditional probability in the category is multiplied by the baseline accident rate. The entire spectrum of accident severities is considered in the accident risk assessment.

As discussed above, the accident consequence assessment only considers the potential impacts from the most severe transportation accidents. In terms of risk, the severity of an accident must be viewed in terms of potential radiological consequences, which are directly proportional to the fraction of the radioactive material within a cask that is released to the environment during the accident. In terms of the modal study accident characterization scheme (Figure E-15), the most severe transportation accidents correspond to those in Regions (4,1), (4,2), (4,3), (4,4), (4,5), (3,5), (2,5), and (1,5). Although these regions span the entire range of mechanical and thermal accident loads considered in the modal study, they are characterized by a single set of release fractions and are therefore considered together in the accident consequence assessment.

The conditional probability of the most severe accidents (i.e., the probability that an accident is of maximum severity, assuming that one has occurred) is found by summing the modal study conditional probabilities for the eight individual accident regions listed above. The resultant overall conditional probability is found to be 0.00000984 for truck transportation and 0.000124 for rail transportation. The stated probabilities encompass the entire spectrum of severe accidents, although over 97 percent of the severe truck accidents and nearly 100 percent of the severe rail accidents actually occur in Region (1,5), which is characterized by high thermal stresses and moderate mechanical stresses.

Structural Response (Maximum Strain on Inner Shell, %)

S_3 (30)	R (4,1)	R (4,2)	R (4,3)	R (4,4)	R (4,5)
S_2 (2)	R (3,1)	R (3,2)	R (3,3)	R (3,4)	R (3,5)
S_1 (0.2)	R (2,1)	R (2,2)	R (2,3)	R (2,4)	R (2,5)
	R (1,1)	R (1,2)	R (1,3)	R (1,4)	R (1,5)

T_1 (500) T_2 (600) T_3 (650) T_4 (1050)

Thermal Response (Lead Mid-Thickness Temperature, °F)

Figure E-14 Matrix of Cask Response Regions for Combined Mechanical and Thermal Loads

Legend:

(P_t) = Probability of occurrence assuming a truck accident occurs.
(P_r) = Probability of occurrence assuming a rail accident occurs.

Structural Response (maximum strain on inner shell, %)

S_3 (30)	R(4,1) (P_t)1.532×10^{-7} (P_r)1.786×10^{-9}	R(4,2) 3.926×10^{-14} 3.290×10^{-13}	R(4,3) 1.495×10^{-14} 2.137×10^{-13}	R(4,4) 7.681×10^{-16} 1.644×10^{-13}	R(4,5) $<1 \times 10^{-16}$ 3.459×10^{-14}
S_2 (2)	R(3,1) (P_t)1.7984×10^{-3} (P_r)5.545×10^{-4}	R(3,2) 1.574×10^{-7} 1.021×10^{-7}	R(3,3) 2.034×10^{-7} 6.634×10^{-8}	R(3,4) 1.076×10^{-7} 5.162×10^{-8}	R(3,5) 4.873×10^{-8} 5.296×10^{-8}
S_1 (0.2)	R(2,1) (P_t)3.8192×10^{-3} (P_r)2.7204×10^{-3}	R(2,2) 2.330×10^{-7} 5.011×10^{-7}	R(2,3) 3.008×10^{-7} 3.255×10^{-7}	R(2,4) 1.592×10^{-7} 2.531×10^{-7}	R(2,5) 7.201×10^{-8} 1.075×10^{-8}
	R(1,1) (P_t)0.994316 (P_r)0.993962	R(1,2) 1.687×10^{-5} 1.2275×10^{-3}	R(1,3) 2.362×10^{-5} 7.9511×10^{-4}	R(1,4) 1.525×10^{-5} 6.140×10^{-4}	R(1,5) 9.570×10^{-6} 1.249×10^{-4}

T_1 (500) T_2 (600) T_3 (650) T_4 (1050)

Thermal Response (lead midthickness temperature, °F)

Figure E-15 Fraction of Truck and Rail Accidents Expected within Each Severity Category, Assuming an Accident Occurs

E.6.4.2 Cask Release Fractions

Radiological consequences are calculated by assigning cask release fractions to each accident severity category. The release fraction is defined as the fraction of the radioactive material in a cask that could be released from the package in a given severity of accident. Release fractions take into account all mechanisms necessary to create a release of radioactive material from a damaged cask to the environment. Release fractions vary according to the spent nuclear fuel type and the physical and chemical characteristics of specific radionuclides within the spent nuclear fuel. For instance, most solid radionuclides are difficult to release in particulate form and are therefore relatively nondispersible. Conversely, gaseous radionuclides are relatively easy to release in the unlikely event that the cask and spent nuclear fuel elements are compromised in an accident.

Cask release fractions are given in Table E-6. Two sets of release fractions were used in the assessment depending on the spent nuclear fuel type, consistent with the SNF&INEL Final EIS (DOE, 1995). Release fractions developed for MTR spent nuclear fuel were used for aluminum-clad fuels including BR-2, RHF, and NRU spent nuclear fuel; Release fractions for TRIGA were used for the PRR-1 spent nuclear fuel.

Table E-6 Release Fractions Spent Nuclear Fuel

Cask Response Region	*Release Fractions*[a]				
	Inert Gas	*Iodine*	*Cesium*	*Ruthenium*	*Particulate*
TRIGA Fuel:					
R(1,1)	0.0	0.0	0.0	0.0	0.0
R(1,2), R(1,3)	0.0099	0.000075	0.000006	8.1×10^{-7}	6.0×10^{-8}
R(2,1), R(2,2), R(2,3)	0.03	0.00025	0.00002	0.0000027	2.0×10^{-7}
R(1,4), R(2,4), R(3,4)	0.39	0.0043	0.0002	0.000048	0.000002
R(3,1), R(3,2), R(3,3)	0.33	0.0025	0.0002	0.000027	0.000002
R(1,5), R(2,5), R(3,5), R(4,5), R(4,1), R(4,2), R(4,3), R(4,4)	0.63	0.043	0.002	0.00048	0.00002
Aluminum and Metallic Fuel:[b]					
R(1,1)	0.0	0.0	0.0	0.0	0.0
R(1,2), R(1,3)	0.0099	1.1×10^{-7}	3.0×10^{-8}	4.1×10^{-9}	3.0×10^{-10}
R(2,1), R(2,2), R(2,3)	0.033	3.5×10^{-7}	1.0×10^{-7}	1.4×10^{-8}	1.0×10^{-9}
R(1,4), R(2,4), R(3,4)	0.39	0.000006	0.000001	2.4×10^{-7}	1.0×10^{-8}
R(3,1), R(3,2), R(3,3)	0.33	0.0000035	0.000001	1.4×10^{-7}	1.0×10^{-8}
R(1,5), R(2,5), R(3,5), R(4,5), R(4,1), R(4,2), R(4,3), R(4,4)	0.63	0.00006	0.00001	0.0000024	1.0×10^{-7}

[a] *The fraction of the radioactive material released from a cask to the environment during an accident.*

[b] *These release fractions are applicable to all non-TRIGA, aluminum-clad fuel.*

For waste shipments of material other than spent nuclear fuel, the modal study results are not applicable. Therefore, more conservative release fractions from NUREG-0170 are used for vitrified high-level waste and target material. The NUREG-0170 recommendations for release fractions for Type B casks, regardless of content, are given below:

NUREG-0170 Severity Category	*Release Fraction*
1	0
2	0
3	0.01
4	0.1
5	1
6	1

Source: NRC, 1977a

The values indicate that in the most severe accidents, 100 percent of the material is released from the cask; a highly conservative assumption for most solid waste forms, and somewhat conservative for a powder or cake-like material. The accident assessment also utilizes the fraction of the release that is aerosolized and the fraction of the aerosol that is respirable. The values for high-level waste and target material (assumed to behave as a loose powdered material) were taken from the recommendations provided in RADTRAN 4. These values are shown below:

Physical Waste Form	*Aerosolized Fraction*	*Respirable Fraction*
Vitrified wastes	0.000001	0.05
Chunks (i.e., calcinated target material)	0.01	0.05
Loose powders (i.e., oxidized target material)	0.1	0.05

Source: Neuhauser and Kanipe, 1993

Therefore, the maximum total respirable release fraction for the most severe accidents is 5×10^{-8} for high-level waste shipments and 0.005 for shipments of target material. The values shown above have been used in the accident calculations for shipments of target material and vitrified material for the foreign research reactor spent nuclear fuel EIS.

E.6.5 Atmospheric Conditions

Radioactive material released to the atmosphere is transported by the wind. The amount of dispersion, or dilution, of the radioactive material concentrations in the air depends on the meteorological conditions at the time of the accident. Because it is impossible to predict the specific location of an overland transportation accident, generic atmospheric conditions were selected for the accident risk and consequence assessments.

For the accident risk assessment, neutral weather conditions (Pasquill Stability Class D with a wind speed of 4 m per sec or 9 mph) were assumed. Since neutral meteorological conditions are the most frequently occurring atmospheric stability condition in the United States, they are most likely to be present in the event of an accident involving a spent nuclear fuel shipment. On the basis of observations from National Weather Service surface meteorological stations at over 300 locations in the United States, on an annual average, neutral conditions (Pasquill Classes C and D) occur about half (50 percent) of the time, while stable (Pasquill Classes E and F) and unstable (Pasquill Class A and B) conditions occur about one-third (33 percent) and one-sixth (17 percent) of the time, respectively (Doty et al., 1976). The neutral category predominates in all seasons, but most frequently in the winter (nearly 60 percent of the observations).

For the accident consequence assessment, doses were assessed under both neutral (Pasquill Stability Class D with a wind speed of 4 m per sec or 9 mph) and stable (Pasquill Stability Class F with a wind speed of 1 m per sec or 2.4 mph) atmospheric conditions. The results calculated for neutral conditions represent the most likely consequences, and the results for stable conditions represent a "worst-case" weather situation.

E.6.6 Health Risk Conversion Factors

The health risk conversion factors used to estimate expected cancer fatalities were taken from International Commission on Radiation Protection Publication 60 (ICRP, 1991): 0.0005 and 0.0004 fatal cancer cases per person-rem for members of the public and workers, respectively. Cancer fatalities and incidence occur over the lifetimes of the exposed populations, and thus are called LCF.

E.6.7 Maximally Exposed Individual Exposure Scenarios

The risk to MEIs has been estimated for a number of hypothetical exposure scenarios during overland transportation using the RISKIND code. The receptors include crew members, departure inspectors, and members of the public exposed during traffic obstructions (traffic jam), while working at a service station, or by living near a port of entry or management site. The dose and risk to MEIs were calculated for given distances and durations of exposure. The distances and durations of exposure for each receptor are similar to those given in previous transportation assessments (DOE, 1987b; DOE, 1995), and are believed to be realistic but conservative. The exposure scenarios considered are the following:

- Crew Members: Truck and rail crew members are not assumed to be occupational radiation workers. Dose estimates are based on realistic locations and estimated travel time, and no credit is taken for shielding in addition to the cask.

- Inspectors (truck and rail): Inspectors are assumed to be either Federal or State vehicle inspectors, and are not assumed to be monitored by a dosimetry program. An average exposure distance of 3 m (10 ft) and an exposure time of 30 minutes (min) is assumed.

- Rail Yard Crew Member: A rail yard crew member is not assumed to be monitored by a dosimetry program. An average exposure distance of 10 m (33 ft) and an exposure time of 2 hr is assumed.

- Resident (truck and rail): A resident is assumed to live 30 m (100 ft) from a port or management site entrance route (truck or rail). Shipments are assumed to pass at a velocity of 24 km per hr (15 mph), and the resident is assumed to be exposed unshielded (i.e., no shielding in addition to the cask, such as that afforded by a structure.) Cumulative doses are assessed for each alternative based on the number of shipments entering or exiting the site and assuming the resident is present for 100 percent of the shipments.

- Person in Traffic Obstruction (truck and rail): A person is assumed to be stopped next to a spent nuclear fuel shipment (due to traffic, etc.). The person is assumed to be exposed (no credit is taken for radiation blocked by the individual's vehicle) at a distance of 1 m (3.3 ft) for a duration of 30 min.

- Person at a Truck Service Station: A person is assumed to be exposed at an average distance of 20 m (66 ft) for a duration of 2 hr. This receptor could be a worker at a truck stop, or a member of the public stopped at the same location.

- Resident Near a Rail Stop: A resident is assumed to live near a rail classification yard. The resident is assumed to be exposed unshielded at a distance of 200 m (660 ft) for a duration of 20 hr.

The largest uncertainty in predicting the dose to MEIs during transportation involves determining the frequency of exposure occurrences. This difficulty results from the uncertainties in future shipment schedules, route selection, and the inherent uncertainty in predicting the frequency of random or chance events. For instance, it is conceivable that an individual could be stopped in traffic next to a shipment of foreign research reactor spent nuclear fuel; however, it is difficult to predict how often the same individual would experience this event. Therefore, for the majority of receptors considered, doses are assessed on a per-event basis. To account for possible multiple exposures, ranges of realistic total doses are discussed qualitatively. One exception is the calculation of the dose to a hypothetical resident living near a port of entry or management site entrance route. For these residents, total doses are calculated based on the number of shipments entering or exiting each site for each of the alternatives.

E.6.8 General RADTRAN Input Parameters

In addition to the specific parameters discussed above, values for a number of general parameters must be specified within the RADTRAN code. These general parameters define basic shipment and traffic characteristics and are specific to the mode of transportation. The RADTRAN code user's manual (Neuhauser and Kanipe, 1993) contains derivations and descriptions of these parameters. The general RADTRAN input parameters used in the transportation risk assessment are summarized in Table E-7.

Table E-7 Summary of General RADTRAN Input Parameters

Parameter	Truck	Rail
Package type	Type B Cask	Type B Cask
Package dimension	3.2 m (10.6 ft)	3.2 m (10.6 ft)
Number of crewmen	2	5
Distance from source to crew	3 m (9.9 ft)	152 m (501.6 ft)
Velocity		
Rural	88 km/hr (55 mph)	64 km/hr (40 mph)
Suburban	40 km/hr (25 mph)	40 km/hr (25 mph)
Urban	24 km/hr (15 mph)	24 km/hr (15 mph)
Stop time per kilometer	0.011 hr/km (0.018 hr/mi)	0.033 hr/km (0.053 hr/mi)
Number of people exposed while stopped	50	Based on Suburban Population Density
Number of people per vehicle sharing route	2	3
Population densities (persons/km^2)	Route Specific (see Table E-4)	Route Specific (see Table E-4)
One-way traffic count (vehicles/hr)		
Rural	470	1
Suburban	780	5
Urban	2,800	5
Cask inventory (Ci)	(see Table E-5)	(see Table E-5)
Accident release fractions	(see Table E-6)	(see Table E-6)
Accident conditional probabilities	(see Figure E-15)	(see Figure E-15)

Source: Neuhauser and Kanipe, 1993.

E.7 Risk Assessment Results

In this section, the risk assessment results are presented for the ports of entry and management sites being considered. The collective population risk results are presented in Section E.7.1. First, the per-shipment risks results are presented in Section E.7.1.1. Then, in Section E.7.1.2, the results are analyzed, evaluated, and simplified so the different program alternatives and options can be evaluated in Section E.7.2.

The risks to MEIs during incident-free transportation conditions are provided in Section E.7.3. The accident consequence results calculated for the most severe transportation accidents are presented in Section E.7.4 for both collective populations and MEIs.

E.7.1 Collective Population Risk Results

E.7.1.1 Per-Shipment Risk Factors

Per-shipment risk factors have been calculated for the collective populations of exposed persons for shipments between all representative ports of entry and the five management sites. Results were calculated for both truck and rail modes, assuming that one cask would be shipped per truck or rail car. Additionally, the risk factors for the ports of Elizabeth, NJ; Philadelphia, PA; and Long Beach, CA are included to show the effect of using high population ports. Risk factors are included for some site-to-site routes, even though there are no shipments anticipated on these routes.

The radiological risks are presented in terms of dose per shipment for each unique route. The doses can be converted to health risks using the International Commission on Radiological Protection Publication 60 conversion factors described in Section E.6.6 (ICRP, 1991). The radiological dose per shipment factors for incident-free transportation conditions are presented in Table E-8 for crew members and members of the general public. The tabulated incident-free doses are based on the external dose rate which is conservatively assumed to be at the regulatory limit of 10 mrem per hr at 2 m. The radiological dose risk factors for accident transportation conditions are presented in Table E-9. The accident risk factors are referred to as "dose risk" because the values incorporate the spectrum of accident severity probabilities and the associated release fractions.

Table E-8 Incident-Free Dose per Shipment for All Spent Nuclear Fuel Types (Person-Rem/Shipment)[a]

Shipments to Hanford Site:						
			General Public			
Route(s)		***Crew***	***Off-Link***	***On-Link***	***Stops***	***Total***
From Eastern Ports						
Charleston, SC (NWS)	Truck	$2.50x10^{-1}$	$9.26x10^{-3}$	$3.96x10^{-2}$	$5.92x10^{-1}$	$6.41x10^{-1}$
	Rail	$6.33x10^{-2}$	$2.91x10^{-2}$	$1.13x10^{-3}$	$1.70x10^{-2}$	$4.73x10^{-2}$
Charleston, SC (Wando Terminal)	Truck	$2.51x10^{-1}$	$9.61x10^{-3}$	$4.03x10^{-2}$	$5.95x10^{-1}$	$6.45x10^{-1}$
	Rail	$6.33x10^{-2}$	$2.91x10^{-2}$	$1.13x10^{-3}$	$1.70x10^{-2}$	$4.73x10^{-2}$
Elizabeth, NJ	Truck	$2.49x10^{-1}$	$9.96x10^{-3}$	$4.10x10^{-2}$	$5.82x10^{-1}$	$6.33x10^{-1}$
	Rail	$6.24x10^{-2}$	$6.03x10^{-2}$	$1.66x10^{-3}$	$1.68x10^{-2}$	$7.88x10^{-2}$
Galveston, TX	Truck	$2.05x10^{-1}$	$1.00x10^{-2}$	$3.77x10^{-2}$	$4.82x10^{-1}$	$5.30x10^{-1}$
	Rail	$5.20x10^{-2}$	$1.31x10^{-2}$	$6.59x10^{-4}$	$1.51x10^{-2}$	$2.88x10^{-2}$
Jacksonville, FL	Truck	$2.60x10^{-1}$	$1.09x10^{-2}$	$4.35x10^{-2}$	$6.05x10^{-1}$	$6.60x10^{-1}$
	Rail	$6.35x10^{-2}$	$2.58x10^{-2}$	$1.08x10^{-3}$	$1.65x10^{-2}$	$4.34x10^{-2}$
Newport News, VA	Truck	$2.57x10^{-1}$	$1.16x10^{-2}$	$4.44x10^{-2}$	$6.02x10^{-1}$	$6.58x10^{-1}$
	Rail	$6.38x10^{-2}$	$4.02x10^{-2}$	$1.25x10^{-3}$	$1.59x10^{-2}$	$5.73x10^{-2}$

Shipments to Hanford Site:							
Route(s)		Crew	General Public				
			Off-Link	On-Link	Stops	Total	
Norfolk, VA	Truck	$2.62x10^{-1}$	$1.19x10^{-2}$	$4.50x10^{-2}$	$6.10x10^{-1}$	$6.67x10^{-1}$
	Rail	$6.54x10^{-2}$	$4.10x10^{-2}$	$1.28x10^{-3}$	$1.67x10^{-2}$	$5.90x10^{-2}$
Philadelphia, PA	Truck	$2.58x10^{-1}$	$1.06x10^{-2}$	$4.31x10^{-2}$	$5.94x10^{-1}$	$6.47x10^{-1}$
	Rail	$6.16x10^{-2}$	$5.90x10^{-2}$	$1.58x10^{-3}$	$1.68x10^{-2}$	$7.74x10^{-2}$
Portsmouth, VA	Truck	$2.61x10^{-1}$	$1.24x10^{-2}$	$4.60x10^{-2}$	$6.07x10^{-1}$	$6.65x10^{-1}$
	Rail	$6.49x10^{-2}$	$3.99x10^{-2}$	$1.25x10^{-3}$	$1.64x10^{-2}$	$5.76x10^{-2}$
Savannah, GA	Truck	$2.48x10^{-1}$	$1.03x10^{-2}$	$4.13x10^{-2}$	$5.82x10^{-1}$	$6.34x10^{-1}$
	Rail	$6.38x10^{-2}$	$2.48x10^{-2}$	$1.08x10^{-3}$	$1.66x10^{-2}$	$4.24x10^{-2}$
MOTSU, NC	Truck	$2.50x10^{-1}$	$9.26x10^{-3}$	$4.00x10^{-2}$	$5.94x10^{-1}$	$6.43x10^{-1}$
	Rail	$6.57x10^{-2}$	$2.85x10^{-2}$	$1.20x10^{-3}$	$1.71x10^{-2}$	$4.68x10^{-2}$
Wilmington, NC	Truck	$2.59x10^{-1}$	$9.34x10^{-3}$	$4.07x10^{-2}$	$6.13x10^{-1}$	$6.63x10^{-1}$
	Rail	$6.56x10^{-2}$	$2.84x10^{-2}$	$1.19x10^{-3}$	$1.71x10^{-2}$	$4.67x10^{-2}$
From Western Ports							
NWS Concord, CA	Truck	$8.06x10^{-2}$	$4.55x10^{-3}$	$1.55x10^{-2}$	$1.77x10^{-1}$	$1.97x10^{-1}$
	Rail	$2.77x10^{-2}$	$1.88x10^{-2}$	$4.83x10^{-4}$	$8.77x10^{-3}$	$2.81x10^{-2}$
Long Beach, CA	Truck	$1.19x10^{-1}$	$1.13x10^{-2}$	$2.98x10^{-2}$	$2.57x10^{-1}$	$2.98x10^{-1}$
	Rail	$3.84x10^{-2}$	$3.71x10^{-2}$	$7.16x10^{-4}$	$1.46x10^{-2}$	$5.25x10^{-2}$
Portland, OR	Truck	$2.35x10^{-2}$	$1.50x10^{-3}$	$4.90x10^{-3}$	$5.24x10^{-2}$	$5.88x10^{-2}$
	Rail	$1.57x10^{-2}$	$4.36x10^{-3}$	$1.12x10^{-4}$	$7.04x10^{-3}$	$1.15x10^{-2}$
Tacoma, WA	Truck	$2.50x10^{-2}$	$1.73x10^{-3}$	$5.45x10^{-3}$	$5.14x10^{-2}$	$5.85x10^{-2}$
	Rail	$1.80x10^{-2}$	$5.69x10^{-3}$	$1.82x10^{-4}$	$6.12x10^{-3}$	$1.20x10^{-2}$
From DOE Sites/Canadian Border							
Alexandria Bay, NY	Truck	$2.49x10^{-1}$	$1.05x10^{-2}$	$4.23x10^{-2}$	$5.73x10^{-1}$	$6.26x10^{-1}$
	Rail	$6.02x10^{-2}$	$5.10x10^{-2}$	$1.40x10^{-3}$	$1.65x10^{-2}$	$6.89x10^{-2}$
Idaho National Engineering Laboratory	Truck	$4.92x10^{-1}$	$1.42x10^{-3}$	$7.63x10^{-3}$	$1.24x10^{-1}$	$1.33x10^{-1}$
	Rail	$2.28x10^{-2}$	$3.88x10^{-3}$	$1.76x10^{-4}$	$7.64x10^{-3}$	$1.17x10^{-2}$
Nevada Test Site	Truck	$9.91x10^{-2}$	$5.37x10^{-3}$	$1.92x10^{-2}$	$2.34x10^{-1}$	$2.58x10^{-1}$
	Rail	$3.36x10^{-1}$	$6.24x10^{-3}$	$3.08x10^{-4}$	$1.12x10^{-2}$	$1.77x10^{-2}$
Oak Ridge Reservation	Truck	$2.10x10^{-1}$	$7.29x10^{-3}$	$3.31x10^{-2}$	$5.10x10^{-1}$	$5.50x10^{-1}$
	Rail	$5.56x10^{-2}$	$1.64x10^{-2}$	$6.92x10^{-4}$	$1.60x10^{-1}$	$3.31x10^{-2}$
Savannah River	Truck	$2.42x10^{-1}$	$1.02x10^{-2}$	$4.01x10^{-2}$	$5.65x10^{-1}$	$6.15x10^{-1}$
	Rail	$6.15x10^{-2}$	$2.74x10^{-2}$	$1.08x10^{-3}$	$1.66x10^{-2}$	$4.51x10^{-2}$
Sweetgrass, MT	Truck	$7.27x10^{-1}$	$1.76x10^{-3}$	$1.03x10^{-2}$	$1.81x10^{-1}$	$1.93x10^{-1}$
	Rail	$2.19x10^{-2}$	$3.81x10^{-3}$	$1.62x10^{-4}$	$7.83x10^{-3}$	$1.18x10^{-2}$

Shipments to Idaho National Engineering Laboratory:						
Route(s)		Crew	General Public			
			Off-Link	On-Link	Stops	Total
From Eastern Ports						
Charleston, SC (NWS)	Truck	$2.16x10^{-1}$	$8.41x10^{-3}$	$3.48x10^{-2}$	$5.05x10^{-1}$	$5.49x10^{-1}$
	Rail	$5.41x10^{-2}$	$2.68x10^{-2}$	$1.01x10^{-3}$	$1.45x10^{-2}$	$4.24x10^{-2}$
Charleston, SC (Wando Terminal)	Truck	$2.18x10^{-1}$	$8.76x10^{-3}$	$3.56x10^{-2}$	$5.09x10^{-1}$	$5.53x10^{-1}$
	Rail	$5.41x10^{-2}$	$2.68x10^{-2}$	$1.01x10^{-3}$	$1.45x10^{-2}$	$4.24x10^{-2}$
Elizabeth, NJ	Truck	$2.15x10^{-1}$	$9.11x10^{-3}$	$3.59x10^{-2}$	$4.96x10^{-1}$	$5.41x10^{-1}$
	Rail	$5.32x10^{-2}$	$5.81x10^{-2}$	$1.53x10^{-3}$	$1.44x10^{-2}$	$7.40x10^{-2}$
Galveston, TX	Truck	$1.71x10^{-1}$	$9.18x10^{-3}$	$3.26x10^{-2}$	$3.96x10^{-1}$	$4.37x10^{-1}$
	Rail	$4.28x10^{-2}$	$1.08x10^{-2}$	$5.35x10^{-4}$	$1.24x10^{-2}$	$2.38x10^{-2}$
Jacksonville, FL	Truck	$2.26x10^{-1}$	$9.78x10^{-3}$	$3.77x10^{-2}$	$5.18x10^{-1}$	$5.66x10^{-1}$
	Rail	$5.42x10^{-2}$	$2.35x10^{-2}$	$9.54x10^{-4}$	$1.40x10^{-2}$	$3.85x10^{-2}$
Newport News, VA	Truck	$2.24x10^{-1}$	$1.08x10^{-2}$	$3.93x10^{-2}$	$5.16x10^{-1}$	$5.66x10^{-1}$
	Rail	$5.45x10^{-2}$	$3.79x10^{-2}$	$1.13x10^{-3}$	$1.35x10^{-2}$	$5.25x10^{-2}$

Shipments to Idaho National Engineering Laboratory:						
Route(s)		***Crew***	***General Public***			
			Off-Link	***On-Link***	***Stops***	***Total***
From Eastern Ports						
Norfolk, VA	Truck	2.28×10^{-1}	1.08×10^{-2}	3.93×10^{-2}	5.24×10^{-1}	5.74×10^{-1}
	Rail	5.62×10^{-2}	3.87×10^{-2}	1.16×10^{-3}	1.43×10^{-2}	5.42×10^{-2}
Philadelphia, PA	Truck	2.24×10^{-1}	9.71×10^{-3}	3.80×10^{-2}	5.08×10^{-1}	5.55×10^{-1}
	Rail	5.24×10^{-2}	5.67×10^{-2}	1.46×10^{-3}	1.44×10^{-2}	7.25×10^{-2}
Portsmouth, VA	Truck	2.27×10^{-1}	1.15×10^{-2}	4.09×10^{-2}	5.20×10^{-1}	5.73×10^{-1}
	Rail	5.57×10^{-2}	3.76×10^{-2}	1.13×10^{-3}	1.40×10^{-2}	5.27×10^{-2}
Savannah, GA	Truck	2.15×10^{-1}	9.41×10^{-3}	3.62×10^{-2}	4.96×10^{-1}	5.42×10^{-1}
	Rail	5.46×10^{-2}	2.25×10^{-2}	9.53×10^{-4}	1.41×10^{-2}	3.75×10^{-2}
MOTSU, NC	Truck	2.11×10^{-1}	7.80×10^{-3}	3.35×10^{-2}	4.98×10^{-1}	5.40×10^{-1}
	Rail	5.65×10^{-2}	2.62×10^{-2}	1.07×10^{-3}	1.47×10^{-2}	4.20×10^{-2}
Wilmington, NC	Truck	2.25×10^{-1}	8.50×10^{-3}	3.56×10^{-2}	5.27×10^{-1}	5.71×10^{-1}
	Rail	5.63×10^{-2}	2.61×10^{-2}	1.07×10^{-3}	1.47×10^{-2}	4.19×10^{-2}
From Western Ports						
NWS Concord, CA	Truck	8.40×10^{-2}	4.84×10^{-3}	1.72×10^{-2}	1.95×10^{-1}	2.17×10^{-1}
	Rail	2.71×10^{-2}	8.71×10^{-3}	2.96×10^{-4}	7.88×10^{-3}	1.69×10^{-2}
Long Beach, CA	Truck	9.93×10^{-2}	1.28×10^{-2}	3.06×10^{-2}	2.03×10^{-1}	2.46×10^{-1}
	Rail	2.92×10^{-2}	3.48×10^{-2}	5.92×10^{-4}	1.20×10^{-2}	4.74×10^{-2}
Portland, OR	Truck	6.27×10^{-2}	2.46×10^{-3}	1.06×10^{-2}	1.53×10^{-1}	1.66×10^{-1}
	Rail	2.49×10^{-2}	5.01×10^{-3}	2.01×10^{-4}	7.23×10^{-3}	1.24×10^{-2}
Tacoma, WA	Truck	7.04×10^{-2}	2.71×10^{-3}	1.19×10^{-2}	1.69×10^{-1}	1.83×10^{-1}
	Rail	2.74×10^{-2}	8.57×10^{-3}	3.04×10^{-4}	7.71×10^{-3}	1.66×10^{-2}
From DOE Sites/Canadian Border						
Alexandria Bay, NY	Truck	2.16×10^{-1}	9.64×10^{-3}	3.72×10^{-2}	4.87×10^{-1}	5.34×10^{-1}
	Rail	5.10×10^{-2}	4.87×10^{-2}	1.28×10^{-3}	1.41×10^{-2}	6.40×10^{-2}
Hanford Site	Truck	4.92×10^{-1}	1.42×10^{-2}	7.63×10^{-2}	1.24×10^{-1}	1.33×10^{-1}
	Rail	2.28×10^{-1}	3.88×10^{-2}	1.76×10^{-3}	7.64×10^{-2}	1.17×10^{-2}
Nevada Test Site	Truck	6.56×10^{-1}	4.52×10^{-2}	1.40×10^{-1}	1.47×10^{-1}	1.66×10^{-1}
	Rail	2.44×10^{-1}	3.95×10^{-2}	1.84×10^{-3}	8.29×10^{-2}	1.24×10^{-2}
Oak Ridge Reservation	Truck	1.76×10^{-1}	6.45×10^{-1}	2.80×10^{-1}	4.24×10^{-1}	4.58×10^{-1}
	Rail	4.63×10^{-1}	1.41×10^{-1}	5.69×10^{-3}	1.33×10^{-1}	2.80×10^{-2}
Savannah River	Truck	2.08×10^{-1}	9.34×10^{-2}	3.50×10^{-1}	4.79×10^{-1}	5.23×10^{-1}
	Rail	5.23×10^{-1}	2.51×10^{-1}	9.56×10^{-3}	1.41×10^{-1}	4.02×10^{-2}
Sweetgrass, MT	Truck	4.25×10^{-1}	6.45×10^{-3}	5.67×10^{-2}	1.12×10^{-1}	1.19×10^{-1}
	Rail	3.24×10^{-1}	5.37×10^{-2}	2.84×10^{-3}	9.14×10^{-2}	1.48×10^{-2}

Shipments to Nevada Test Site:						
Route(s)		***Crew***	***General Public***			
			Off-Link	***On-Link***	***Stops***	***Total***
From Eastern Ports						
Charleston, SC (NWS)	Truck	2.25×10^{-1}	9.15×10^{-3}	3.69×10^{-2}	5.27×10^{-1}	5.73×10^{-1}
	Rail	6.13×10^{-2}	2.95×10^{-2}	1.11×10^{-3}	1.69×10^{-2}	4.75×10^{-2}
Charleston, SC (Wando Terminal)	Truck	2.27×10^{-1}	9.50×10^{-3}	3.76×10^{-2}	5.30×10^{-1}	5.77×10^{-1}
	Rail	6.13×10^{-2}	2.95×10^{-2}	1.11×10^{-3}	1.69×10^{-2}	4.75×10^{-2}
Elizabeth, NJ	Truck	2.48×10^{-1}	1.35×10^{-2}	4.60×10^{-2}	5.53×10^{-1}	6.13×10^{-1}
	Rail	6.05×10^{-2}	6.07×10^{-3}	1.63×10^{-3}	1.66×10^{-2}	7.8×10^{-2}
Jacksonville, FL	Truck	2.35×10^{-1}	1.10×10^{-2}	4.07×10^{-2}	5.40×10^{-1}	5.91×10^{-1}
	Rail	6.15×10^{-2}	2.61×10^{-2}	1.05×10^{-3}	1.64×10^{-2}	4.36×10^{-2}
Newport News, VA	Truck	2.33×10^{-1}	1.20×10^{-2}	4.23×10^{-2}	5.37×10^{-1}	5.92×10^{-1}
	Rail	6.18×10^{-2}	4.05×10^{-2}	1.22×10^{-3}	1.57×10^{-2}	5.75×10^{-2}

Shipments to Nevada Test Site:							
Route(s)		Crew	General Public				
			Off-Link	On-Link	Stops	Total
Norfolk, VA	Truck	2.73×10^{-1}	1.19×10^{-2}	4.23×10^{-2}	5.45×10^{-1}	5.99×10^{-1}
	Rail	6.35×10^{-2}	4.14×10^{-2}	1.2×10^{-3}	1.66×10^{-2}	5.92×10^{-2}
Philadelphia, PA	Truck	2.44×10^{-1}	1.30×10^{-2}	4.49×10^{-2}	5.43×10^{-1}	6.01×10^{-1}
	Rail	5.97×10^{-2}	5.94×10^{-2}	1.56×10^{-3}	1.66×10^{-2}	7.75×10^{-2}
Portsmouth, VA	Truck	2.36×10^{-1}	1.27×10^{-2}	4.39×10^{-2}	5.42×10^{-1}	5.98×10^{-1}
	Rail	6.30×10^{-2}	4.3×10^{-2}	1.23×10^{-3}	1.63×10^{-2}	5.78×10^{-2}
Savannah, GA	Truck	2.24×10^{-1}	1.06×10^{-2}	3.92×10^{-2}	5.18×10^{-1}	5.67×10^{-1}
	Rail	6.19×10^{-2}	2.51×10^{-2}	1.05×10^{-3}	1.64×10^{-2}	4.26×10^{-2}
MOTSU, NC	Truck	2.22×10^{-1}	1.06×10^{-2}	3.95×10^{-2}	5.09×10^{-1}	5.59×10^{-1}
	Rail	6.38×10^{-2}	2.89×10^{-2}	1.17×10^{-3}	1.70×10^{-2}	4.70×10^{-2}
Wilmington, NC	Truck	2.35×10^{-1}	9.67×10^{-3}	3.86×10^{-2}	5.49×10^{-1}	5.97×10^{-1}
	Rail	6.36×10^{-2}	2.88×10^{-2}	1.16×10^{-3}	1.70×10^{-2}	4.69×10^{-2}
From Western Ports						
NWS Concord, CA	Truck	6.88×10^{-2}	8.04×10^{-3}	1.99×10^{-2}	1.47×10^{-1}	1.75×10^{-1}
	Rail	2.60×10^{-2}	1.83×10^{-2}	4.73×10^{-4}	8.17×10^{-3}	2.70×10^{-2}
Long Beach, CA	Truck	4.63×10^{-2}	9.79×10^{-3}	2.04×10^{-2}	8.30×10^{-2}	1.13×10^{-1}
	Rail	1.98×10^{-2}	3.09×10^{-2}	4.37×10^{-4}	9.63×10^{-3}	4.10×10^{-2}
Portland, OR	Truck	1.13×10^{-1}	6.62×10^{-3}	2.28×10^{-2}	2.63×10^{-1}	2.92×10^{-1}
	Rail	3.58×10^{-2}	7.38×10^{-3}	3.33×10^{-1}	1.10×10^{-2}	1.87×10^{-2}
Tacoma, WA	Truck	1.20×10^{-1}	6.66×10^{-3}	2.34×10^{-2}	2.78×10^{-1}	3.08×10^{-1}
	Rail	3.83×10^{-2}	1.09×10^{-2}	4.36×10^{-4}	1.11×10^{-2}	2.24×10^{-2}
From DOE Sites/Canadian Border						
Alexandria Bay, NY	Truck	2.39×10^{-1}	1.11×10^{-2}	4.21×10^{-2}	5.42×10^{-1}	5.95×10^{-1}
	Rail	5.83×10^{-2}	5.13×10^{-2}	1.37×10^{-3}	1.63×10^{-2}	6.90×10^{-2}
Hanford Site	Truck	9.91×10^{-2}	5.37×10^{-3}	1.92×10^{-2}	2.34×10^{-1}	2.58×10^{-1}
	Rail	3.36×10^{-2}	6.24×10^{-3}	3.08×10^{-1}	1.12×10^{-2}	1.77×10^{-2}
Idaho National Engineering Laboratory	Truck	6.56×10^{-2}	4.52×10^{-3}	1.40×10^{-2}	1.47×10^{-1}	1.66×10^{-1}
	Rail	2.44×10^{-2}	3.95×10^{-3}	1.84×10^{-1}	8.29×10^{-3}	1.24×10^{-2}
Oak Ridge Reservation	Truck	1.86×10^{-1}	7.6×10^{-3}	3.10×10^{-2}	4.45×10^{-1}	4.84×10^{-1}
	Rail	5.36×10^{-2}	1.68×10^{-2}	6.66×10^{-1}	1.63×10^{-2}	3.37×10^{-2}
Savannah River	Truck	2.17×10^{-1}	1.05×10^{-2}	3.80×10^{-2}	5.00×10^{-1}	5.48×10^{-1}
	Rail	5.96×10^{-2}	2.77×10^{-2}	1.05×10^{-3}	1.65×10^{-2}	4.53×10^{-2}

Shipments to Oak Ridge Reservation:						
Route(s)		General Public				
		Crew	Off-Link	On-Link	Stops	Total
From Eastern Ports						
Charleston, SC (NWS)	Truck	3.98×10^{-2}	1.73×10^{-3}	6.11×10^{-3}	8.32×10^{-2}	9.11×10^{-2}
	Rail	2.15×10^{-2}	6.88×10^{-3}	3.60×10^{-4}	5.33×10^{-3}	1.26×10^{-2}
Charleston, SC (Wando Terminal)	Truck	4.18×10^{-2}	2.09×10^{-3}	6.85×10^{-3}	8.63×10^{-2}	9.53×10^{-2}
	Rail	2.15×10^{-2}	6.88×10^{-3}	3.60×10^{-4}	5.33×10^{-3}	1.26×10^{-2}
Elizabeth, NJ	Truck	8.02×10^{-2}	4.85×10^{-3}	1.45×10^{-2}	1.53×10^{-1}	1.72×10^{-1}
	Rail	2.49×10^{-2}	4.30×10^{-2}	9.20×10^{-4}	7.73×10^{-3}	5.17×10^{-2}
Galveston, TX	Truck	9.53×10^{-2}	5.71×10^{-3}	1.73×10^{-2}	1.99×10^{-1}	2.22×10^{-1}
	Rail	2.94×10^{-2}	1.87×10^{-2}	6.28×10^{-4}	8.98×10^{-3}	2.83×10^{-2}
Jacksonville, FL	Truck	5.88×10^{-2}	2.88×10^{-3}	9.64×10^{-3}	1.17×10^{-1}	1.30×10^{-1}
	Rail	2.12×10^{-2}	8.80×10^{-3}	3.59×10^{-4}	6.51×10^{-3}	1.57×10^{-2}
Newport News, VA	Truck	5.68×10^{-2}	3.57×10^{-3}	1.09×10^{-2}	1.15×10^{-1}	1.29×10^{-1}
	Rail	2.45×10^{-2}	1.11×10^{-2}	5.45×10^{-4}	6.00×10^{-3}	1.77×10^{-2}
Norfolk, VA	Truck	5.63×10^{-2}	2.85×10^{-3}	9.27×10^{-3}	1.14×10^{-1}	1.26×10^{-1}
	Rail	2.33×10^{-2}	8.51×10^{-3}	4.56×10^{-4}	5.63×10^{-3}	1.46×10^{-2}

Shipments to Oak Ridge Reservation:						
Route(s)		***Crew***	***General Public***			
			Off-Link	***On-Link***	***Stops***	***Total***
Philadelphia, PA	Truck	$7.36x10^{-2}$	$5.74x10^{-3}$	$1.56x10^{-2}$	$1.41x10^{-1}$	$1.62x10^{-1}$
	Rail	$2.35x10^{-2}$	$2.83x10^{-2}$	$7.16x10^{-4}$	$6.98x10^{-3}$	$3.60x10^{-2}$
Portsmouth, VA	Truck	$6.01x10^{-2}$	$4.32x10^{-3}$	$1.25x10^{-2}$	$1.19x10^{-1}$	$1.36x10^{-1}$
	Rail	$2.28x10^{-2}$	$7.44x10^{-3}$	$4.30x10^{-4}$	$5.31x10^{-3}$	$1.32x10^{-2}$
Savannah, GA	Truck	$4.33x10^{-2}$	$1.61x10^{-3}$	$6.44x10^{-3}$	$9.29x10^{-2}$	$1.01x10^{-1}$
	Rail	$2.16x10^{-2}$	$7.78x10^{-3}$	$3.58x10^{-4}$	$6.58x10^{-3}$	$1.47x10^{-2}$
MOTSU, NC	Truck	$4.88x10^{-2}$	$2.07x10^{-3}$	$7.52x10^{-3}$	$1.03x10^{-1}$	$1.12x10^{-1}$
	Rail	$2.08x10^{-2}$	$6.52x10^{-3}$	$3.63x10^{-4}$	$5.04x10^{-3}$	$1.19x10^{-2}$
Wilmington, NC	Truck	$5.00x10^{-2}$	$2.06x10^{-3}$	$7.70x10^{-3}$	$1.05x10^{-1}$	$1.15x10^{-1}$
	Rail	$2.06x10^{-2}$	$6.41x10^{-3}$	$3.55x10^{-4}$	$5.00x10^{-3}$	$1.18x10^{-2}$
From Western Ports						
NWS Concord, CA	Truck	$2.26x10^{-1}$	$1.32x10^{-2}$	$4.47x10^{-2}$	$5.29x10^{-1}$	$5.87x10^{-1}$
	Rail	$5.91x10^{-2}$	$2.76x10^{-2}$	$9.50x10^{-4}$	$1.71x10^{-2}$	$4.57x10^{-2}$
Long Beach, CA	Truck	$2.03x10^{-1}$	$1.49x10^{-2}$	$4.52x10^{-2}$	$4.65x10^{-1}$	$5.25x10^{-1}$
	Rail	$5.68x10^{-2}$	$4.55x10^{-2}$	$1.06x10^{-3}$	$1.73x10^{-2}$	$6.39x10^{-2}$
Portland, OR	Truck	$2.25x10^{-1}$	$8.88x10^{-3}$	$3.72x10^{-2}$	$5.40x10^{-1}$	$5.86x10^{-1}$
	Rail	$5.94x10^{-2}$	$3.16x10^{-2}$	$1.05x10^{-3}$	$1.78x10^{-2}$	$5.04x10^{-2}$
Tacoma, WA	Truck	$2.26x10^{-1}$	$7.26x10^{-3}$	$3.44x10^{-2}$	$5.50x10^{-1}$	$5.92x10^{-1}$
	Rail	$5.95x10^{-2}$	$3.86x10^{-2}$	$1.17x10^{-3}$	$1.85x10^{-2}$	$5.83x10^{-2}$
From DOE Sites/Canadian Border						
Alexandria Bay, NY	Truck	$9.64x10^{-2}$	$4.11x10^{-3}$	$1.46x10^{-2}$	$1.92x10^{-1}$	$2.11x10^{-1}$
	Rail	$2.80x10^{-2}$	$3.17x10^{-2}$	$8.38x10^{-4}$	$9.07x10^{-3}$	$4.16x10^{-2}$
Hanford Site	Truck	$2.10x10^{-1}$	$7.29x10^{-2}$	$3.31x10^{-1}$	$5.10x10^{-1}$	$5.50x10^{-1}$
	Rail	$5.56x10^{-1}$	$1.64x10^{-1}$	$6.92x10^{-3}$	$1.60x10^{-1}$	$3.31x10^{-2}$
Idaho National Engineering Laboratory	Truck	$1.76x10^{-1}$	$6.45x10^{-2}$	$2.80x10^{-1}$	$4.24x10^{-1}$	$4.58x10^{-1}$
	Rail	$4.63x10^{-1}$	$1.41x10^{-1}$	$5.69x10^{-3}$	$1.33x10^{-1}$	$2.80x10^{-2}$
Nevada Test Site	Truck	$1.86x10^{-1}$	$7.63x10^{-2}$	$3.10x10^{-1}$	$4.45x10^{-1}$	$4.84x10^{-1}$
	Rail	$5.36x10^{-1}$	$1.68x10^{-1}$	$6.66x10^{-3}$	$1.63x10^{-1}$	$3.37x10^{-2}$
Savannah River	Truck	$4.23x10^{-1}$	$2.93x10^{-2}$	$7.96x10^{-2}$	$7.84x10^{-1}$	$8.93x10^{-1}$
	Rail	$1.87x10^{-1}$	$4.69x10^{-2}$	$2.38x10^{-3}$	$5.11x10^{-2}$	$1.00x10^{-2}$
Sweetgrass, MT	Truck	$1.94x10^{-1}$	$5.82x10^{-2}$	$2.93x10^{-1}$	$4.79x10^{-1}$	$5.14x10^{-1}$
	Rail	$4.70x10^{-1}$	$2.57x10^{-1}$	$8.41x10^{-3}$	$1.46x10^{-1}$	$4.11x10^{-2}$

Shipments to Savannah River Site:						
Route(s)		***Crew***	***General Public***			
			Off-Link	***On-Link***	***Stops***	***Total***
From Eastern Ports						
Charleston, SC (NWS)	Truck	$1.84x10^{-2}$	$7.44x10^{-4}$	$2.83x10^{-3}$	$3.89x10^{-2}$	$4.25x10^{-2}$
	Rail	$1.40x10^{-2}$	$1.77x10^{-3}$	$5.53x10^{-6}$	$4.77x10^{-3}$	$6.59x10^{-3}$
Charleston, SC (Wando Terminal)	Truck	$2.04x10^{-2}$	$1.10x10^{-3}$	$3.57x10^{-3}$	$4.21x10^{-2}$	$4.67x10^{-2}$
	Rail	$1.40x10^{-2}$	$1.77x10^{-3}$	$5.53x10^{-6}$	$4.77x10^{-3}$	$6.59x10^{-3}$
Elizabeth, NJ	Truck	$8.83x10^{-2}$	$5.31x10^{-3}$	$1.60x10^{-2}$	$1.70x10^{-1}$	$1.92x10^{-1}$
	Rail	$2.64x10^{-2}$	$4.14x10^{-2}$	$8.55x10^{-4}$	$8.08x10^{-3}$	$5.04x10^{-2}$
Galveston, TX	Truck	$1.02x10^{-1}$	$6.82x10^{-3}$	$1.94x10^{-2}$	$2.07x10^{-1}$	$2.33x10^{-1}$
	Rail	$3.15x10^{-2}$	$2.48x10^{-2}$	$7.41x10^{-4}$	$1.04x10^{-2}$	$3.59x10^{-2}$
Jacksonville, FL	Truck	$3.37x10^{-2}$	$7.25x10^{-4}$	$4.42x10^{-3}$	$7.81x10^{-2}$	$8.32x10^{-2}$
	Rail	$1.60x10^{-2}$	$3.06x10^{-3}$	$1.04x10^{-4}$	$4.61x10^{-3}$	$7.77x10^{-3}$
Newport News, VA	Truck	$5.24x10^{-2}$	$3.06x10^{-3}$	$9.51x10^{-3}$	$1.07x10^{-1}$	$1.20x10^{-1}$
	Rail	$2.18x10^{-2}$	$8.37x10^{-3}$	$3.55x10^{-4}$	$5.66x10^{-3}$	$1.44x10^{-2}$
Norfolk, VA	Truck	$4.89x10^{-2}$	$2.13x10^{-3}$	$7.66x10^{-3}$	$1.03x10^{-1}$	$1.13x10^{-1}$
	Rail	$2.06x10^{-2}$	$5.78x10^{-3}$	$2.66x10^{-4}$	$5.22x10^{-3}$	$1.13x10^{-2}$

Shipments to Savannah River Site:							
			General Public				
Route(s)		Crew	Off-Link	On-Link	Stops	Total	
Philadelphia, PA	Truck	8.21×10^{-2}	6.81×10^{-3}	1.78×10^{-2}	1.53×10^{-1}	1.78×10^{-1}	
	Rail	2.50×10^{-2}	2.67×10^{-2}	6.51×10^{-4}	7.21×10^{-3}	3.46×10^{-2}	
Portsmouth, VA	Truck	4.93×10^{-2}	2.21×10^{-3}	7.90×10^{-3}	1.04×10^{-1}	1.14×10^{-1}	
	Rail	2.01×10^{-2}	4.71×10^{-3}	2.39×10^{-4}	4.72×10^{-3}	9.67×10^{-3}	
Savannah, GA	Truck	2.29×10^{-2}	5.78×10^{-4}	3.04×10^{-3}	5.18×10^{-2}	5.54×10^{-2}	
	Rail	1.36×10^{-2}	8.37×10^{-4}	3.51×10^{-5}	4.39×10^{-3}	5.27×10^{-3}	
MOTSU, NC	Truck	2.22×10^{-2}	5.41×10^{-4}	3.06×10^{-3}	5.17×10^{-2}	5.53×10^{-2}	
	Rail	1.81×10^{-2}	3.82×10^{-3}	1.73×10^{-4}	4.51×10^{-3}	8.50×10^{-3}	
Wilmington, NC	Truck	2.96×10^{-2}	1.03×10^{-3}	4.30×10^{-3}	6.42×10^{-2}	6.95×10^{-2}	
	Rail	1.79×10^{-2}	3.71×10^{-3}	1.65×10^{-4}	4.46×10^{-3}	8.33×10^{-3}	
From Western Ports							
NWS Concord, CA	Truck	2.64×10^{-1}	1.83×10^{-2}	5.52×10^{-2}	5.76×10^{-1}	6.50×10^{-1}	
	Rail	6.54×10^{-2}	5.17×10^{-2}	1.52×10^{-3}	1.88×10^{-2}	7.20×10^{-2}	
Long Beach, CA	Truck	2.33×10^{-1}	1.61×10^{-2}	4.83×10^{-2}	5.06×10^{-1}	5.70×10^{-1}	
	Rail	6.63×10^{-2}	5.65×10^{-2}	1.51×10^{-3}	1.80×10^{-2}	7.60×10^{-2}	
Portland, OR	Truck	2.57×10^{-1}	1.17×10^{-2}	4.42×10^{-2}	5.96×10^{-1}	6.52×10^{-1}	
	Rail	6.49×10^{-2}	3.88×10^{-2}	1.34×10^{-3}	1.81×10^{-2}	5.82×10^{-2}	
Seattle, WA	Truck	2.54×10^{-1}	9.50×10^{-3}	4.00×10^{-2}	6.00×10^{-1}	6.50×10^{-1}	
	Rail	6.44×10^{-2}	4.13×10^{-2}	1.37×10^{-3}	1.82×10^{-2}	6.09×10^{-2}	
Tacoma, WA	Truck	2.58×10^{-1}	1.02×10^{-2}	4.15×10^{-2}	6.07×10^{-1}	6.59×10^{-1}	
	Rail	6.51×10^{-2}	4.59×10^{-2}	1.45×10^{-3}	1.87×10^{-2}	6.60×10^{-2}	
From DOE Sites/Canadian Border							
Alexandria Bay, NY	Truck	1.04×10^{-1}	4.58×10^{-3}	1.61×10^{-2}	2.10×10^{-1}	2.30×10^{-1}	
	Rail	3.33×10^{-2}	6.15×10^{-2}	1.30×10^{-3}	9.18×10^{-3}	7.20×10^{-2}	
Hanford Site	Truck	2.42×10^{-1}	1.02×10^{-2}	4.01×10^{-2}	5.65×10^{-1}	6.15×10^{-1}	
	Rail	6.15×10^{-2}	2.74×10^{-2}	1.08×10^{-3}	1.66×10^{-2}	4.51×10^{-2}	
Idaho National Engineering Laboratory	Truck	2.08×10^{-1}	9.34×10^{-3}	3.50×10^{-2}	4.79×10^{-1}	5.23×10^{-1}	
	Rail	5.23×10^{-2}	2.51×10^{-2}	9.56×10^{-4}	1.41×10^{-2}	4.02×10^{-2}	
Nevada Test Site	Truck	2.17×10^{-1}	1.05×10^{-2}	3.80×10^{-2}	5.00×10^{-1}	5.48×10^{-1}	
	Rail	5.96×10^{-2}	2.77×10^{-2}	1.05×10^{-3}	1.65×10^{-2}	4.53×10^{-2}	
Oak Ridge Reservation	Truck	4.23×10^{-2}	2.93×10^{-3}	7.96×10^{-3}	7.84×10^{-2}	8.93×10^{-2}	
	Rail	1.87×10^{-2}	4.69×10^{-3}	2.38×10^{-4}	5.11×10^{-3}	1.00×10^{-2}	
Sweetgrass, MT	Truck	2.26×10^{-1}	8.66×10^{-3}	3.62×10^{-2}	5.33×10^{-1}	5.78×10^{-1}	
	Rail	5.26×10^{-2}	3.30×10^{-2}	1.13×10^{-3}	1.49×10^{-2}	4.90×10^{-2}	

[a] *Incident free risk factors are based on dose rates of 10 mrem per hr at 2 m (6.6 ft) (the regulatory limit).*

MOTSU = Military Ocean Terminal at Sunny Point, NWS = Naval Weapons Station

Table E-9 Accident Dose Risk per Shipment for All Spent Nuclear Fuel Types (Person-Rem/shipment)

Shipments to Hanford Site:		
Source/Route	Truck	Rail
From Eastern Ports		
BR-2 Belgium Spent Nuclear Fuel		
Charleston, SC (NWS)	1.51×10^{-4}	2.06×10^{-5}
Charleston, SC (Wando Terminal)	1.54×10^{-4}	2.06×10^{-5}
Elizabeth, NJ	1.30×10^{-4}	4.19×10^{-5}
Galveston, TX	9.53×10^{-5}	8.81×10^{-6}
Jacksonville, FL	1.71×10^{-4}	1.86×10^{-5}

Shipments to Hanford Site:		
Source/Route	***Truck***	***Rail***
Newport News, VA	$1.44x10^{-4}$	$3.28x10^{-5}$
Norfolk, VA	$1.47x10^{-4}$	$3.33x10^{-5}$
Philadelphia, PA	$1.31x10^{-4}$	$3.75x10^{-5}$
Portsmouth, VA	$1.49x10^{-4}$	$3.28x10^{-5}$
Savannah, GA	$1.65x10^{-4}$	$1.86x10^{-5}$
MOTSU, NC	$1.45x10^{-4}$	$2.14x10^{-5}$
Wilmington, NC	$1.51x10^{-4}$	$2.13x10^{-5}$
RHF France Spent Nuclear Fuel		
Charleston, SC (NWS)	$6.54x10^{-5}$	$8.86x10^{-6}$
Charleston, SC (Wando Terminal)	$6.67x10^{-5}$	$8.86x10^{-6}$
Elizabeth, NJ	$5.59x10^{-5}$	$1.80x10^{-5}$
Galveston, TX	$4.12x10^{-5}$	$3.80x10^{-6}$
Jacksonville, FL	$7.39x10^{-5}$	$8.00x10^{-6}$
Newport News, VA	$6.21x10^{-5}$	$1.41x10^{-5}$
Norfolk, VA	$6.35x10^{-5}$	$1.43x10^{-5}$
Philadelphia, PA	$5.67x10^{-5}$	$1.61x10^{-5}$
Portsmouth, VA	$6.44x10^{-5}$	$1.41x10^{-5}$
Savannah, GA	$7.11x10^{-5}$	$8.03x10^{-6}$
MOTSU, NC	$6.28x10^{-5}$	$9.20x10^{-6}$
Wilmington, NC	$6.51x10^{-5}$	$9.15x10^{-6}$
NRU Canada Spent Nuclear Fuel		
Charleston, SC (NWS)	$2.09x10^{-4}$	$2.86x10^{-5}$
Charleston, SC (Wando Terminal)	$2.13x10^{-4}$	$2.86x10^{-5}$
Elizabeth, NJ	$1.79x10^{-4}$	$5.83x10^{-5}$
Galveston, TX	$1.32x10^{-4}$	$1.22x10^{-5}$
Jacksonville, FL	$2.36x10^{-4}$	$2.58x10^{-5}$
Newport News, VA	$1.99x10^{-4}$	$4.56x10^{-5}$
Norfolk, VA	$2.03x10^{-4}$	$4.64x10^{-5}$
Philadelphia, PA	$1.82x10^{-4}$	$5.22x10^{-5}$
Portsmouth, VA	$2.06x10^{-4}$	$4.57x10^{-5}$
Savannah, GA	$2.27x10^{-4}$	$2.59x10^{-5}$
MOTSU, NC	$2.01x10^{-4}$	$2.97x10^{-5}$
Wilmington, NC	$2.08x10^{-4}$	$2.95x10^{-5}$
PRR-1 TRIGA Spent Nuclear Fuel		
Charleston, SC (NWS)	$4.33x10^{-4}$	$9.80x10^{-5}$
Charleston, SC (Wando Terminal)	$4.40x10^{-4}$	$9.80x10^{-5}$
Elizabeth, NJ	$4.49x10^{-4}$	$2.11x10^{-4}$
Galveston, TX	$2.68x10^{-4}$	$3.71x10^{-5}$
Jacksonville, FL	$4.81x10^{-4}$	$9.21x10^{-5}$
Newport News, VA	$4.23x10^{-4}$	$1.83x10^{-4}$
Norfolk, VA	$4.31x10^{-4}$	$1.85x10^{-4}$
Philadelphia, PA	$4.63x10^{-4}$	$1.97x10^{-4}$
Portsmouth, VA	$4.36x10^{-4}$	$1.84x10^{-4}$
Savannah, GA	$4.64x10^{-4}$	$9.25x10^{-5}$
MOTSU, NC	$4.27x10^{-4}$	$1.01x10^{-4}$
Wilmington, NC	$4.32x10^{-4}$	$1.01x10^{-4}$
Calcined Target Material		
Charleston, SC (NWS)	$3.96x10^{-2}$	$7.21x10^{-3}$
Charleston, SC (Wando Terminal)	$3.98x10^{-2}$	$7.21x10^{-3}$
Elizabeth, NJ	$6.73x10^{-2}$	$1.66x10^{-2}$
Jacksonville, FL	$4.09x10^{-2}$	$7.17x10^{-3}$

Shipments to Hanford Site:		
Source/Route	**Truck**	**Rail**
Newport News, VA	$4.22x10^{-2}$	$1.62x10^{-2}$
Norfolk, VA	$4.27x10^{-2}$	$1.63x10^{-2}$
Philadelphia, PA	$7.31x10^{-2}$	$1.62x10^{-2}$
Portsmouth, VA	$4.25x10^{-2}$	$1.63x10^{-2}$
Savannah, GA	$4.01x10^{-2}$	$7.21x10^{-3}$
MOTSU, NC	$4.35x10^{-2}$	$7.41x10^{-3}$
Wilmington, NC	$4.07x10^{-2}$	$7.40x10^{-3}$
Galveston, TX	$2.25x10^{-2}$	$2.16x10^{-3}$
Oxidized Target Material		
Charleston, SC (NWS)	$9.91x10^{-2}$	$1.80x10^{-2}$
Charleston, SC (Wando Terminal)	$9.95x10^{-2}$	$1.80x10^{-2}$
Elizabeth, NJ	$1.68x10^{-1}$	$4.14x10^{-2}$
Jacksonville, FL	$1.02x10^{-1}$	$1.79x10^{-2}$
Newport News, VA	$1.05x10^{-1}$	$4.06x10^{-2}$
Norfolk, VA	$1.07x10^{-1}$	$4.09x10^{-2}$
Philadelphia, PA	$1.83x10^{-1}$	$4.06x10^{-2}$
Portsmouth, VA	$1.06x10^{-1}$	$4.08x10^{-2}$
Savannah, GA	$1.00x10^{-1}$	$1.80x10^{-2}$
MOTSU, NC	$1.09x10^{-1}$	$1.85x10^{-2}$
Wilmington, NC	$1.02x10^{-1}$	$1.85x10^{-2}$
Galveston, TX	$5.62x10^{-2}$	$5.40x10^{-3}$
From Western Ports		
BR-2 Belgium Spent Nuclear Fuel		
NWS, Concord CA	$4.46x10^{-5}$	$1.50x10^{-5}$
Long Beach, CA	$7.36x10^{-5}$	$1.59x10^{-5}$
Portland, OR	$1.15x10^{-5}$	$2.10x10^{-6}$
Tacoma, WA	$8.55x10^{-6}$	$2.08x10^{-6}$
RHF France Spent Nuclear Fuel		
NWS, Concord CA	$1.93x10^{-5}$	$6.47x10^{-6}$
Long Beach, CA	$3.18x10^{-5}$	$6.86x10^{-6}$
Portland, OR	$4.99x10^{-6}$	$9.08x10^{-7}$
Tacoma, WA	$3.69x10^{-6}$	$8.99x10^{-7}$
NRU Canada Spent Nuclear Fuel		
NWS Concord, CA	$6.15x10^{-5}$	$2.07x10^{-5}$
Long Beach, CA	$1.02x10^{-4}$	$2.20x10^{-5}$
Portland, OR	$1.59x10^{-5}$	$2.91x10^{-6}$
Tacoma, WA	$1.18x10^{-5}$	$2.88x10^{-6}$
PRR-1 TRIGA Spent Nuclear Fuel		
NWS Concord, CA	$1.15x10^{-4}$	$5.15x10^{-5}$
Long Beach, CA	$1.90x10^{-4}$	$5.50x10^{-5}$
Portland, OR	$2.97x10^{-5}$	$7.50x10^{-6}$
Tacoma, WA	$2.46x10^{-5}$	$7.79x10^{-6}$
Calcined Target Material		
NWS Concord, CA	$4.92x10^{-3}$	$1.50x10^{-3}$
Long Beach, CA	$7.06x10^{-3}$	$1.63x10^{-3}$
Portland, OR	$1.28x10^{-3}$	$2.54x10^{-4}$
Tacoma, WA	$1.90x10^{-3}$	$3.11x10^{-4}$
Oxidized Target Material		
NWS Concord, CA	$1.23x10^{-2}$	$3.75x10^{-3}$
Long Beach, CA	$1.77x10^{-2}$	$4.08x10^{-3}$
Portland, OR	$3.21x10^{-3}$	$6.36x10^{-4}$

Shipments to Hanford Site:		
Source/Route	***Truck***	***Rail***
Tacoma, WA	$4.75x10^{-3}$	$7.80x10^{-4}$
From DOE Sites/Canadian Border		
BR-2 Belgium Spent Nuclear Fuel		
Alexandria Bay, NY	$1.52x10^{-4}$	$3.76x10^{-5}$
Idaho National Engineering Laboratory	$1.00x10^{-5}$	$3.08x10^{-6}$
Nevada Test Site	$5.07x10^{-5}$	$4.62x10^{-6}$
Oak Ridge Reservation	$1.13x10^{-4}$	$1.16x10^{-5}$
Savannah River	$1.61x10^{-4}$	$1.97x10^{-5}$
Sweetgrass, MT	$2.25x10^{-5}$	$1.56x10^{-6}$
RHF France Spent Nuclear Fuel		
Alexandria Bay, NY	$6.56x10^{-5}$	$1.62x10^{-5}$
Idaho National Engineering Laboratory	$4.33x10^{-6}$	$1.33x10^{-6}$
Nevada Test Site	$2.19x10^{-5}$	$1.99x10^{-6}$
Oak Ridge Reservation	$4.86x10^{-5}$	$4.97x10^{-6}$
Savannah River	$6.94x10^{-5}$	$8.47x10^{-6}$
Sweetgrass, MT	$9.72x10^{-6}$	$6.72x10^{-7}$
NRU Canada Spent Nuclear Fuel		
Alexandria Bay, NY	$2.10x10^{-4}$	$5.23x10^{-5}$
Idaho National Engineering Laboratory	$1.38x10^{-5}$	$4.27x10^{-6}$
Nevada Test Site	$6.99x10^{-5}$	$6.39x10^{-6}$
Oak Ridge Reservation	$1.56x10^{-4}$	$1.62x10^{-5}$
Savannah River	$2.22x10^{-4}$	$2.73x10^{-5}$
Sweetgrass, MT	$3.11x10^{-5}$	$2.16x10^{-6}$
PRR-1 TRIGA Spent Nuclear Fuel		
Alexandria Bay, NY	$4.99x10^{-4}$	$1.98x10^{-4}$
Idaho National Engineering Laboratory	$2.94x10^{-5}$	$1.21x10^{-5}$
Nevada Test Site	$1.29x10^{-4}$	$1.74x10^{-5}$
Oak Ridge Reservation	$3.35x10^{-4}$	$7.04x10^{-5}$
Savannah River	$4.53x10^{-4}$	$9.49x10^{-5}$
Sweetgrass, MT	$6.49x10^{-5}$	$6.18x10^{-6}$
Calcined Target Material		
Alexandria Bay, NY	$6.72x10^{-2}$	$1.63x10^{-2}$
Idaho National Engineering Laboratory	$2.69x10^{-3}$	$5.83x10^{-4}$
Nevada Test Site	$4.74x10^{-3}$	$7.41x10^{-4}$
Oak Ridge Reservation	$3.55x10^{-2}$	$6.78x10^{-3}$
Savannah River	$3.96x10^{-2}$	$7.11x10^{-3}$
Sweetgrass, MT	$6.01x10^{-3}$	$3.03x10^{-4}$
Oxidized Target Material		
Alexandria Bay, NY	$1.68x10^{-1}$	$4.07x10^{-2}$
Idaho National Engineering Laboratory	$6.74x10^{-3}$	$1.46x10^{-3}$
Nevada Test Site	$1.19x10^{-2}$	$1.85x10^{-3}$
Oak Ridge Reservation	$8.88x10^{-2}$	$1.70x10^{-2}$
Savannah River	$9.90x10^{-2}$	$1.78x10^{-2}$
Sweetgrass, MT	$1.50x10^{-2}$	$7.57x10^{-4}$

Shipments to Idaho National Engineering Laboratory:		
Source/Route	***Truck***	***Rail***
From Eastern Ports		
BR-2 Belgium Spent Nuclear Fuel		
Charleston, SC (NWS)	$1.45x10^{-4}$	$1.85x10^{-5}$
Charleston, SC (Wando Terminal)	$1.48x10^{-4}$	$1.85x10^{-5}$
Elizabeth, NJ	$1.23x10^{-4}$	$3.98x10^{-5}$

Shipments to Idaho National Engineering Laboratory:		
Source/Route	***Truck***	***Rail***
Galveston, TX	8.88×10^{-5}	6.71×10^{-6}
Jacksonville, FL	1.62×10^{-4}	1.65×10^{-5}
Newport News, VA	1.37×10^{-4}	3.07×10^{-5}
Norfolk, VA	1.39×10^{-4}	3.12×10^{-5}
Philadelphia, PA	1.25×10^{-4}	3.54×10^{-5}
Portsmouth, VA	1.43×10^{-4}	3.07×10^{-5}
Savannah, GA	1.58×10^{-4}	1.66×10^{-5}
MOTSU, NC	1.34×10^{-4}	1.93×10^{-5}
Wilmington, NC	1.44×10^{-4}	1.92×10^{-5}
RHF France Spent Nuclear Fuel		
Charleston, SC (NWS)	6.26×10^{-5}	7.96×10^{-6}
Charleston, SC (Wando Terminal)	6.39×10^{-5}	7.96×10^{-6}
Elizabeth, NJ	5.31×10^{-5}	1.71×10^{-5}
Galveston, TX	3.84×10^{-5}	2.89×10^{-6}
Jacksonville, FL	7.02×10^{-5}	7.10×10^{-6}
Newport News, VA	5.93×10^{-5}	1.32×10^{-5}
Norfolk, VA	6.01×10^{-5}	1.34×10^{-5}
Philadelphia, PA	5.39×10^{-5}	1.52×10^{-5}
Portsmouth, VA	6.16×10^{-5}	1.32×10^{-5}
Savannah, GA	6.83×10^{-5}	7.12×10^{-6}
MOTSU, NC	5.78×10^{-5}	8.30×10^{-6}
Wilmington, NC	6.22×10^{-5}	8.25×10^{-6}
NRU Canada Spent Nuclear Fuel		
Charleston, SC (NWS)	2.00×10^{-4}	2.57×10^{-5}
Charleston, SC (Wando Terminal)	2.04×10^{-4}	2.57×10^{-5}
Elizabeth, NJ	1.23×10^{-4}	5.54×10^{-5}
Galveston, TX	1.70×10^{-4}	9.29×10^{-6}
Jacksonville, FL	2.24×10^{-4}	2.29×10^{-5}
Newport News, VA	1.90×10^{-4}	4.27×10^{-5}
Norfolk, VA	1.92×10^{-4}	4.35×10^{-5}
Portsmouth, VA	1.97×10^{-4}	4.28×10^{-5}
Savannah, GA	2.18×10^{-4}	2.30×10^{-5}
MOTSU, NC	1.85×10^{-4}	2.68×10^{-5}
Wilmington, NC	1.99×10^{-4}	2.66×10^{-5}
PRR-1 TRIGA Spent Nuclear Fuel		
Charleston, SC (NWS)	4.14×10^{-4}	8.94×10^{-5}
Charleston, SC (Wando Terminal)	4.21×10^{-4}	8.94×10^{-5}
Elizabeth, NJ	4.30×10^{-4}	2.02×10^{-4}
Galveston, TX	4.49×10^{-4}	8.47×10^{-5}
Jacksonville, FL	4.57×10^{-4}	8.36×10^{-5}
Newport News, VA	4.04×10^{-4}	1.75×10^{-4}
Norfolk, VA	4.09×10^{-4}	1.77×10^{-4}
Philadelphia, PA	4.44×10^{-4}	1.88×10^{-4}
Portsmouth, VA	4.17×10^{-4}	1.75×10^{-4}
Savannah, GA	4.45×10^{-4}	8.39×10^{-5}
MOTSU, NC	3.97×10^{-4}	9.26×10^{-5}
Wilmington, NC	4.13×10^{-4}	9.22×10^{-5}
Calcined Target Material		
Charleston, SC (NWS)	3.79×10^{-2}	6.76×10^{-3}
Charleston, SC (Wando Terminal)	3.81×10^{-2}	6.76×10^{-3}
Elizabeth, NJ	6.57×10^{-2}	1.61×10^{-2}

Shipments to Idaho National Engineering Laboratory:		
Source/Route	***Truck***	***Rail***
Jacksonville, FL	$3.91x10^{-2}$	$6.72x10^{-3}$
Newport News, VA	$4.05x10^{-2}$	$1.58x10^{-2}$
Norfolk, VA	$4.10x10^{-2}$	$1.59x10^{-2}$
Philadelphia, PA	$7.15x10^{-2}$	$1.58x10^{-2}$
Portsmouth, VA	$4.09x10^{-2}$	$1.59x10^{-2}$
Savannah, GA	$3.84x10^{-2}$	$6.76x10^{-3}$
MOTSU, NC	$4.18x10^{-2}$	$6.96x10^{-3}$
Wilmington, NC	$3.91x10^{-2}$	$6.95x10^{-3}$
Galveston, TX	$2.08x10^{-2}$	$1.71x10^{-3}$
Oxidized Target Material		
Charleston, SC (NWS)	$9.49x10^{-2}$	$1.69x10^{-2}$
Charleston, SC (Wando Terminal)	$9.53x10^{-2}$	$1.69x10^{-2}$
Elizabeth, NJ	$1.64x10^{-1}$	$4.03x10^{-2}$
Jacksonville, FL	$9.79x10^{-2}$	$1.68x10^{-2}$
Newport News, VA	$1.01x10^{-1}$	$3.95x10^{-2}$
Norfolk, VA	$1.03x10^{-1}$	$3.98x10^{-2}$
Philadelphia, PA	$1.79x10^{-1}$	$3.95x10^{-2}$
Portsmouth, VA	$1.02x10^{-1}$	$3.96x10^{-2}$
Savannah, GA	$9.62x10^{-2}$	$1.69x10^{-2}$
MOTSU, NC	$1.05x10^{-1}$	$1.74x10^{-2}$
Wilmington, NC	$9.78x10^{-2}$	$1.74x10^{-2}$
Galveston, TX	$5.21x10^{-2}$	$4.28x10^{-3}$
From Western Ports		
BR-2 Belgium Spent Nuclear Fuel		
NWS Concord, CA	$3.83x10^{-5}$	$4.00x10^{-6}$
Long Beach, CA	$7.40x10^{-5}$	$1.38x10^{-5}$
Portland, OR	$1.93x10^{-5}$	$4.94x10^{-6}$
Tacoma, WA	$1.66x10^{-5}$	$6.85x10^{-6}$
RHF France Spent Nuclear Fuel		
NWS Concord, CA	$1.66x10^{-5}$	$1.73x10^{-6}$
Long Beach, CA	$3.20x10^{-5}$	$5.96x10^{-6}$
Portland, OR	$8.35x10^{-6}$	$2.13x10^{-6}$
Tacoma, WA	$7.19x10^{-6}$	$2.95x10^{-6}$
NRU Canada Spent Nuclear Fuel		
NWS Concord, CA	$5.29x10^{-5}$	$5.53x10^{-6}$
Long Beach, CA	$1.02x10^{-4}$	$1.91x10^{-5}$
Portland, OR	$2.67x10^{-5}$	$6.84x10^{-6}$
Tacoma, WA	$2.30x10^{-5}$	$9.47x10^{-6}$
PRR-1 TRIGA Spent Nuclear Fuel		
NWS Concord, CA	$9.68x10^{-5}$	$1.42x10^{-5}$
Long Beach, CA	$1.85x10^{-4}$	$4.64x10^{-5}$
Portland, OR	$5.19x10^{-5}$	$1.85x10^{-5}$
Tacoma, WA	$4.88x10^{-5}$	$2.50x10^{-5}$
Calcined Target Material		
NWS Concord, CA	$3.21x10^{-3}$	$4.70x10^{-4}$
Long Beach, CA	$4.75x10^{-3}$	$1.18x10^{-3}$
Portland, OR	$3.23x10^{-3}$	$7.61x10^{-4}$
Tacoma, WA	$4.35x10^{-3}$	$9.55x10^{-4}$
Oxidized Target Material		
NWS Concord, CA	$8.05x10^{-3}$	$1.18x10^{-3}$
Long Beach, CA	$1.19x10^{-2}$	$2.95x10^{-3}$

Shipments to Idaho National Engineering Laboratory:		
Source/Route	***Truck***	***Rail***
Portland, OR	8.07×10^{-3}	1.91×10^{-3}
Tacoma, WA	1.09×10^{-2}	2.39×10^{-3}
From DOE Sites/Canadian Border		
BR-2 Belgium Spent Nuclear Fuel		
Alexandria Bay, NY	1.45×10^{-4}	3.55×10^{-5}
Hanford Site	1.00×10^{-5}	3.08×10^{-6}
Nevada Test Site	4.41×10^{-5}	2.52×10^{-6}
Oak Ridge Reservation	1.06×10^{-4}	9.48×10^{-6}
Savannah River	1.54×10^{-4}	1.76×10^{-5}
Sweetgrass, MT	1.59×10^{-5}	3.84×10^{-6}
RHF France Spent Nuclear Fuel		
Hanford Site	4.33×10^{-6}	1.33×10^{-6}
Nevada Test Site	1.91×10^{-5}	1.09×10^{-6}
Oak Ridge Reservation	4.58×10^{-5}	4.07×10^{-6}
Savannah River	6.66×10^{-5}	7.57×10^{-6}
NRU Canada Spent Nuclear Fuel		
Alexandria Bay, NY	2.01×10^{-4}	4.94×10^{-5}
Hanford Site	1.38×10^{-5}	4.27×10^{-6}
Nevada Test Site	6.09×10^{-5}	3.48×10^{-6}
Oak Ridge Reservation	1.46×10^{-4}	1.33×10^{-5}
Savannah River	2.13×10^{-4}	2.44×10^{-5}
Sweetgrass, MT	2.20×10^{-5}	5.32×10^{-6}
PRR-1 TRIGA Spent Nuclear Fuel		
Hanford Site	2.94×10^{-5}	1.21×10^{-5}
Nevada Test Site	1.09×10^{-4}	8.79×10^{-6}
Oak Ridge Reservation	3.16×10^{-4}	6.19×10^{-5}
Savannah River	4.34×10^{-4}	8.63×10^{-5}
Calcined Target Material		
Alexandria Bay, NY	6.55×10^{-2}	1.58×10^{-2}
Hanford Site	2.69×10^{-3}	5.83×10^{-4}
Nevada Test Site	3.10×10^{-3}	2.90×10^{-4}
Oak Ridge Reservation	3.38×10^{-2}	6.33×10^{-3}
Savannah River	3.79×10^{-2}	6.66×10^{-3}
Sweetgrass, MT	3.56×10^{-3}	8.19×10^{-4}
Oxidized Target Material		
Alexandria Bay, NY	1.64×10^{-1}	3.96×10^{-2}
Hanford	6.74×10^{-3}	1.46×10^{-3}
Nevada Test Site	7.76×10^{-3}	7.27×10^{-4}
Oak Ridge Reservation	8.47×10^{-2}	1.58×10^{-2}
Savannah River	9.49×10^{-2}	1.67×10^{-2}
Sweetgrass, MT	8.91×10^{-3}	2.05×10^{-3}

Shipments to Nevada Test Site:		
Source/Route	***Truck***	***Rail***
From Eastern Ports		
BR-2 Belgium Spent Nuclear Fuel		
Charleston, SC (NWS)	1.65×10^{-4}	1.99×10^{-5}
Charleston, SC (Wando Terminal)	1.68×10^{-4}	1.99×10^{-5}
Elizabeth, NJ	1.77×10^{-4}	4.12×10^{-5}
Galveston, TX	9.13×10^{-5}	5.16×10^{-6}
Jacksonville, FL	1.89×10^{-4}	1.79×10^{-5}
Newport News, VA	1.64×10^{-4}	3.21×10^{-5}

Shipments to Nevada Test Site:		
Source/Route	***Truck***	***Rail***
Norfolk, VA	$1.66x10^{-4}$	$3.27x10^{-5}$
Philadelphia, PA	$1.75x10^{-4}$	$3.68x10^{-5}$
Portsmouth, VA	$1.69x10^{-4}$	$3.22x10^{-5}$
Savannah, GA	$1.85x10^{-4}$	$1.80x10^{-5}$
MOTSU, NC	$1.65x10^{-4}$	$2.07x10^{-5}$
Wilmington, NC	$1.71x10^{-4}$	$2.06x10^{-5}$
RHF France Spent Nuclear Fuel		
Charleston, SC (NWS)	$7.12x10^{-5}$	$8.57x10^{-6}$
Charleston, SC (Wando Terminal)	$7.25x10^{-5}$	$8.57x10^{-6}$
Elizabeth, NJ	$7.66x10^{-5}$	$1.78x10^{-5}$
Galveston, TX	$3.95x10^{-5}$	$2.42x10^{-6}$
Jacksonville, FL	$8.17x10^{-5}$	$7.71x10^{-6}$
Newport News, VA	$7.08x10^{-5}$	$1.38x10^{-5}$
Norfolk, VA	$7.16x10^{-5}$	$1.40x10^{-5}$
Philadelphia, PA	$7.56x10^{-5}$	$1.58x10^{-5}$
Portsmouth, VA	$7.31x10^{-5}$	$1.38x10^{-5}$
Savannah, GA	$7.98x10^{-5}$	$7.74x10^{-6}$
MOTSU, NC	$7.14x10^{-5}$	$8.91x10^{-6}$
Wilmington, NC	$7.37x10^{-5}$	$8.86x10^{-6}$
NRU Canada Spent Nuclear Fuel		
Charleston, SC (NWS)	$2.27x10^{-4}$	$2.76x10^{-5}$
Charleston, SC (Wando Terminal)	$2.32x10^{-4}$	$2.76x10^{-5}$
Elizabeth, NJ	$2.45x10^{-4}$	$5.73x10^{-5}$
Galveston, TX	$1.26x10^{-4}$	$7.77x10^{-6}$
Jacksonville, FL	$2.61x10^{-4}$	$2.49x10^{-5}$
Newport News, VA	$2.26x10^{-4}$	$4.47x10^{-5}$
Norfolk, VA	$2.29x10^{-4}$	$4.55x10^{-5}$
Philadelphia, PA	$2.42x10^{-4}$	$5.12x10^{-5}$
Portsmouth, VA	$2.34x10^{-4}$	$4.48x10^{-5}$
Savannah, GA	$2.55x10^{-4}$	$2.50x10^{-5}$
MOTSU, NC	$2.28x10^{-4}$	$2.87x10^{-5}$
Wilmington, NC	$2.36x10^{-4}$	$2.86x10^{-5}$
PRR-1 TRIGA Spent Nuclear Fuel		
Charleston, SC (NWS)	$4.62x10^{-4}$	$9.35x10^{-5}$
Charleston, SC (Wando Terminal)	$4.69x10^{-4}$	$9.35x10^{-5}$
Elizabeth, NJ	$5.19x10^{-4}$	$2.07x10^{-4}$
Galveston, TX	$2.37x10^{-4}$	$2.44x10^{-5}$
Jacksonville, FL	$5.21x10^{-4}$	$8.77x10^{-5}$
Newport News, VA	$4.68x10^{-4}$	$1.79x10^{-4}$
Norfolk, VA	$4.73x10^{-4}$	$1.81x10^{-4}$
Philadelphia, PA	$5.17x10^{-4}$	$1.92x10^{-4}$
Portsmouth, VA	$4.81x10^{-4}$	$1.79x10^{-4}$
Savannah, GA	$5.10x10^{-4}$	$8.80x10^{-5}$
MOTSU, NC	$4.19x10^{-4}$	$9.67x10^{-5}$
Wilmington, NC	$4.78x10^{-4}$	$9.63x10^{-5}$
20 yr old vitrified HLW		
Charleston, SC (NWS)	$1.40x10^{-3}$	$2.33x10^{-4}$
Charleston, SC (Wando Terminal)	$1.42x10^{-3}$	$2.33x10^{-4}$
Elizabeth, NJ	$1.70x10^{-3}$	$5.33x10^{-4}$
Jacksonville, FL	$1.45x10^{-3}$	$2.27x10^{-4}$
Newport News, VA	$1.45x10^{-3}$	$5.06x10^{-4}$

Shipments to Nevada Test Site:		
Source/Route	**Truck**	**Rail**
Norfolk, VA	$1.47x10^{-3}$	$5.10x10^{-4}$
Philadelphia, PA	$1.73x10^{-3}$	$5.14x10^{-4}$
Portsmouth, VA	$1.46x10^{-3}$	$5.07x10^{-4}$
Savannah, GA	$1.42x10^{-3}$	$2.28x10^{-4}$
MOTSU, NC	$7.07x10^{-4}$	$2.40x10^{-4}$
Wilmington, NC	$1.44x10^{-3}$	$2.40x10^{-4}$
Galveston, TX	$4.20x10^{-4}$	$4.70x10^{-5}$
Calcined Target Material		
Charleston, SC (NWS)	$3.90x10^{-2}$	$6.78x10^{-3}$
Charleston, SC (Wando Terminal)	$3.92x10^{-2}$	$6.78x10^{-3}$
Elizabeth, NJ	$4.86x10^{-2}$	$1.61x10^{-2}$
Jacksonville, FL	$4.03x10^{-2}$	$6.74x10^{-3}$
Newport News, VA	$4.16x10^{-2}$	$1.58x10^{-2}$
Norfolk, VA	$4.21x10^{-2}$	$1.59x10^{-2}$
Philadelphia, PA	$5.03x10^{-2}$	$1.58x10^{-2}$
Portsmouth, VA	$4.20x10^{-2}$	$1.59x10^{-2}$
Savannah, GA	$3.96x10^{-2}$	$6.78x10^{-3}$
MOTSU, NC	$1.79x10^{-2}$	$6.98x10^{-3}$
Wilmington, NC	$4.02x10^{-2}$	$6.97x10^{-3}$
Galveston, TX	$1.11x10^{-2}$	$1.43x10^{-3}$
Oxidized Target Material		
Charleston, SC (NWS)	$9.76x10^{-2}$	$1.70x10^{-2}$
Charleston, SC (Wando Terminal)	$9.81x10^{-2}$	$1.70x10^{-2}$
Elizabeth, NJ	$1.22x10^{-1}$	$4.04x10^{-2}$
Jacksonville, FL	$1.01x10^{-1}$	$1.69x10^{-2}$
Newport News, VA	$1.04x10^{-1}$	$3.95x10^{-2}$
Norfolk, VA	$1.05x10^{-1}$	$3.98x10^{-2}$
Philadelphia, PA	$1.26x10^{-1}$	$3.95x10^{-2}$
Portsmouth, VA	$1.05x10^{-1}$	$3.97x10^{-2}$
Savannah, GA	$9.90x10^{-2}$	$1.70x10^{-2}$
MOTSU, NC	$4.48x10^{-2}$	$1.75x10^{-2}$
Wilmington, NC	$1.01x10^{-1}$	$1.74x10^{-2}$
Galveston, TX	$2.78x10^{-2}$	$3.57x10^{-3}$
From Western Ports		
BR-2 Belgium Spent Nuclear Fuel		
NWS Concord, CA	$4.88x10^{-5}$	$8.09x10^{-6}$
Long Beach, CA	$5.28x10^{-5}$	$1.13x10^{-5}$
Portland, OR	$6.10x10^{-5}$	$6.48x10^{-6}$
Tacoma, WA	$5.73x10^{-5}$	$8.38x10^{-6}$
RHF France Spent Nuclear Fuel		
NWS Concord, CA	$2.11x10^{-5}$	$3.49x10^{-6}$
Long Beach, CA	$2.28x10^{-5}$	$4.89x10^{-6}$
Portland, OR	$2.64x10^{-5}$	$2.80x10^{-6}$
Tacoma, WA	$2.48x10^{-5}$	$3.62x10^{-6}$
NRU Canada Spent Nuclear Fuel		
NWS Concord, CA	$6.73x10^{-5}$	$1.12x10^{-5}$
Long Beach, CA	$7.28x10^{-5}$	$1.56x10^{-5}$
Portland, OR	$8.41x10^{-5}$	$8.96x10^{-6}$
Tacoma, WA	$7.91x10^{-5}$	$1.16x10^{-5}$
PRR-1 TRIGA Spent Nuclear Fuel		
NWS Concord, CA	$1.26x10^{-4}$	$2.91x10^{-5}$

Shipments to Nevada Test Site:		
Source/Route	***Truck***	***Rail***
Long Beach, CA	$1.31x10^{-4}$	$3.77x10^{-5}$
Portland, OR	$1.53x10^{-4}$	$2.37x10^{-5}$
Tacoma, WA	$1.48x10^{-4}$	$3.02x10^{-5}$
Calcined Target Material		
NWS Concord, CA	$4.13x10^{-3}$	$9.39x10^{-4}$
Long Beach, CA	$2.42x10^{-3}$	$8.94x10^{-4}$
Portland, OR	$5.26x10^{-3}$	$9.19x10^{-4}$
Tacoma, WA	$6.39x10^{-3}$	$1.11x10^{-3}$
Oxidized Target Material		
NWS Concord, CA	$1.03x10^{-2}$	$2.35x10^{-3}$
Long Beach, CA	$6.05x10^{-3}$	$2.24x10^{-3}$
Portland, OR	$1.32x10^{-2}$	$2.30x10^{-3}$
Tacoma, WA	$1.60x10^{-2}$	$2.79x10^{-3}$
From DOE Sites/Canadian Border		
BR-2 Belgium Spent Nuclear Fuel		
Alexandria Bay, NY	$1.79x10^{-4}$	$3.69x10^{-5}$
Hanford Site	$5.07x10^{-5}$	$4.62x10^{-6}$
Idaho National Engineering Laboratory	$4.41x10^{-5}$	$2.52x10^{-6}$
Oak Ridge Reservation	$1.33x10^{-4}$	$1.09x10^{-5}$
Savannah River	$1.81x10^{-4}$	$1.90x10^{-5}$
Sweetgrass, MT	$6.08x10^{-5}$	$5.38x10^{-6}$
RHF France Spent Nuclear Fuel		
Alexandria Bay, NY	$7.71x10^{-5}$	$1.59x10^{-5}$
Hanford Site	$2.19x10^{-5}$	$1.99x10^{-6}$
Idaho National Engineering Laboratory	$1.91x10^{-5}$	$1.09x10^{-6}$
Oak Ridge Reservation	$5.73x10^{-5}$	$4.68x10^{-6}$
Savannah River	$7.81x10^{-5}$	$8.18x10^{-6}$
Sweetgrass, MT	$2.63x10^{-5}$	$2.32x10^{-6}$
NRU Canada Spent Nuclear Fuel		
Alexandria Bay, NY	$2.47x10^{-4}$	$5.14x10^{-5}$
Hanford Site	$6.99x10^{-5}$	$6.39x10^{-6}$
Idaho National Engineering Laboratory	$6.09x10^{-5}$	$3.48x10^{-6}$
Oak Ridge Reservation	$1.83x10^{-4}$	$1.52x10^{-5}$
Savannah River	$2.49x10^{-4}$	$2.64x10^{-5}$
Sweetgrass, MT	$8.38x10^{-5}$	$7.45x10^{-6}$
PRR-1 TRIGA Spent Nuclear Fuel		
Alexandria Bay, NY	$5.58x10^{-4}$	$1.93x10^{-4}$
Hanford Site	$1.29x10^{-4}$	$1.74x10^{-5}$
Idaho National Engineering Laboratory	$1.09x10^{-4}$	$8.79x10^{-6}$
Oak Ridge Reservation	$3.81x10^{-4}$	$6.60x10^{-5}$
Savannah River	$4.99x10^{-4}$	$9.04x10^{-5}$
Sweetgrass MT	$1.54x10^{-4}$	$2.09x10^{-5}$
Calcined Target Material		
Alexandria Bay, NY	$6.55x10^{-2}$	$1.58x10^{-2}$
Hanford	$4.74x10^{-3}$	$7.41x10^{-4}$
Idaho National Engineering Laboratory	$3.10x10^{-3}$	$2.90x10^{-4}$
Oak Ridge Reservation	$3.50x10^{-2}$	$6.35x10^{-3}$
Savannah River	$3.91x10^{-2}$	$6.68x10^{-3}$
Sweetgrass, MT	$6.29x10^{-3}$	$9.78x10^{-4}$
Oxidized Target Material		
Alexandria Bay, NY	$1.64x10^{-1}$	$3.96x10^{-2}$

Shipments to Nevada Test Site:		
Source/Route	Truck	Rail
Hanford	$1.19x10^{-2}$	$1.85x10^{-3}$
Idaho National Engineering Laboratory	$7.76x10^{-3}$	$7.27x10^{-4}$
Oak Ridge Reservation	$8.75x10^{-2}$	$1.59x10^{-2}$
Savannah River	$9.77x10^{-2}$	$1.67x10^{-2}$
Sweetgrass, MT	$1.58x10^{-2}$	$2.45x10^{-3}$

Shipments to Oak Ridge Reservation:		
Source/Route	Truck	Rail
From Eastern Ports		
BR-2 Belgium Spent Nuclear Fuel		
Charleston, SC (NWS)	$3.28x10^{-5}$	$5.39x10^{-6}$
Charleston, SC (Wando Terminal)	$3.59x10^{-5}$	$5.39x10^{-6}$
Elizabeth, NJ	$5.86x10^{-5}$	$2.60x10^{-5}$
Galveston, TX	$6.99x10^{-5}$	$1.77x10^{-5}$
Jacksonville, FL	$4.98x10^{-5}$	$6.73x10^{-6}$
Newport News, VA	$4.20x10^{-5}$	$7.94x10^{-6}$
Norfolk, VA	$3.90x10^{-5}$	$6.68x10^{-6}$
Philadelphia, PA	$6.36x10^{-5}$	$1.76x10^{-5}$
Portsmouth, VA	$4.74x10^{-5}$	$6.18x10^{-6}$
Savannah, GA	$3.20x10^{-5}$	$6.79x10^{-6}$
MOTSU, NC	$3.60x10^{-5}$	$5.33x10^{-6}$
Wilmington, NC	$3.85x10^{-5}$	$5.22x10^{-6}$
RHF France Spent Nuclear Fuel		
Charleston, SC (NWS)	$1.42x10^{-5}$	$2.33x10^{-6}$
Charleston, SC (Wando Terminal)	$1.55x10^{-5}$	$2.33x10^{-6}$
Elizabeth, NJ	$2.53x10^{-5}$	$1.13x10^{-5}$
Galveston, TX	$3.02x10^{-5}$	$7.64x10^{-6}$
Jacksonville, FL	$2.15x10^{-5}$	$2.91x10^{-6}$
Newport News, VA	$1.81x10^{-5}$	$3.43x10^{-6}$
Norfolk, VA	$1.69x10^{-5}$	$2.88x10^{-6}$
Philadelphia, PA	$2.75x10^{-5}$	$7.60x10^{-6}$
Portsmouth, VA	$2.05x10^{-5}$	$2.67x10^{-6}$
Savannah, GA	$1.38x10^{-5}$	$2.93x10^{-6}$
MOTSU, NC	$1.56x10^{-5}$	$2.30x10^{-6}$
Wilmington, NC	$1.66x10^{-5}$	$2.25x10^{-6}$
NRU Canada Spent Nuclear Fuel		
Charleston, SC (NWS)	$4.53x10^{-5}$	$7.45x10^{-6}$
Charleston, SC (Wando Terminal)	$4.95x10^{-5}$	$7.45x10^{-6}$
Elizabeth, NJ	$8.08x10^{-5}$	$3.60x10^{-5}$
Galveston, TX	$9.63x10^{-5}$	$2.44x10^{-5}$
Jacksonville, FL	$6.86x10^{-5}$	$9.30x10^{-6}$
Newport News, VA	$5.79x10^{-5}$	$1.10x10^{-5}$
Norfolk, VA	$5.38x10^{-5}$	$9.23x10^{-6}$
Philadelphia, PA	$8.77x10^{-5}$	$2.43x10^{-5}$
Portsmouth, VA	$6.53x10^{-5}$	$8.54x10^{-6}$
Savannah, GA	$4.41x10^{-5}$	$9.38x10^{-6}$
MOTSU, NC	$4.97x10^{-5}$	$7.36x10^{-6}$
Wilmington, NC	$5.31x10^{-5}$	$7.21x10^{-6}$
PRR-1 TRIGA Spent Nuclear Fuel		
Charleston, SC (NWS)	$8.32x10^{-5}$	$1.94x10^{-5}$
Charleston, SC (Wando Terminal)	$9.06x10^{-5}$	$1.94x10^{-5}$
Elizabeth, NJ	$1.53x10^{-4}$	$8.64x10^{-5}$

Shipments to Oak Ridge Reservation:		
Source/Route	***Truck***	***Rail***
Galveston, TX	1.75×10^{-4}	6.15×10^{-5}
Jacksonville, FL	1.26×10^{-4}	2.40×10^{-5}
Newport News, VA	1.09×10^{-4}	2.84×10^{-5}
Norfolk, VA	1.01×10^{-4}	2.43×10^{-5}
Philadelphia, PA	1.66×10^{-4}	5.90×10^{-5}
Portsmouth, VA	1.22×10^{-4}	2.26×10^{-5}
Savannah, GA	8.13×10^{-5}	2.43×10^{-5}
MOTSU, NC	9.18×10^{-5}	1.94×10^{-5}
Wilmington, NC	9.85×10^{-5}	1.90×10^{-5}
Calcined Target Material		
Charleston, SC (NWS)	4.14×10^{-3}	7.70×10^{-4}
Charleston, SC (Wando Terminal)	4.32×10^{-3}	7.70×10^{-4}
Elizabeth, NJ	8.03×10^{-3}	2.18×10^{-3}
Jacksonville, FL	5.87×10^{-3}	9.16×10^{-4}
Newport News, VA	5.46×10^{-3}	1.10×10^{-3}
Norfolk, VA	5.50×10^{-3}	9.94×10^{-4}
Philadelphia, PA	8.57×10^{-3}	1.59×10^{-3}
Portsmouth, VA	5.79×10^{-3}	9.45×10^{-4}
Savannah, GA	4.19×10^{-3}	9.55×10^{-4}
MOTSU, NC	4.78×10^{-3}	8.03×10^{-4}
Wilmington, NC	5.32×10^{-3}	7.89×10^{-4}
Galveston, TX	7.44×10^{-3}	2.10×10^{-3}
Oxidized Target Material		
Charleston, SC (NWS)	1.04×10^{-2}	1.93×10^{-3}
Charleston, SC (Wando Terminal)	1.08×10^{-2}	1.93×10^{-3}
Elizabeth, NJ	2.01×10^{-2}	5.46×10^{-3}
Jacksonville, FL	1.47×10^{-2}	2.30×10^{-3}
Newport News, VA	1.37×10^{-2}	2.76×10^{-3}
Norfolk, VA	1.38×10^{-2}	2.49×10^{-3}
Philadelphia, PA	2.15×10^{-2}	3.97×10^{-3}
Portsmouth, VA	1.45×10^{-2}	2.37×10^{-3}
Savannah, GA	1.05×10^{-2}	2.39×10^{-3}
MOTSU, NC	1.20×10^{-2}	2.01×10^{-3}
Wilmington, NC	1.33×10^{-2}	1.98×10^{-3}
Galveston, TX	1.86×10^{-2}	5.25×10^{-3}
	From Western Ports	
BR-2 Belgium Spent Nuclear Fuel		
NWS Concord, CA	1.46×10^{-4}	1.56×10^{-5}
Long Beach, CA	1.50×10^{-4}	2.08×10^{-5}
Portland, OR	1.33×10^{-4}	2.40×10^{-5}
Tacoma, WA	1.20×10^{-4}	2.55×10^{-5}
RHF France Spent Nuclear Fuel		
NWS Concord, CA	6.33×10^{-5}	6.72×10^{-6}
Long Beach, CA	6.50×10^{-5}	8.97×10^{-6}
Portland, OR	5.75×10^{-5}	1.03×10^{-5}
Tacoma, WA	5.16×10^{-5}	1.10×10^{-5}
NRU Canada Spent Nuclear Fuel		
NWS Concord, CA	2.02×10^{-4}	2.17×10^{-5}
Long Beach, CA	2.07×10^{-4}	2.89×10^{-5}
Portland, OR	1.84×10^{-4}	3.35×10^{-5}
Tacoma, WA	1.65×10^{-4}	3.56×10^{-5}

Shipments to Oak Ridge Reservation:		
Source/Route	**Truck**	**Rail**
PRR-1 TRIGA Spent Nuclear Fuel		
NWS Concord, CA	3.81×10^{-4}	7.68×10^{-5}
Long Beach, CA	3.86×10^{-4}	9.42×10^{-5}
Portland, OR	3.85×10^{-4}	1.25×10^{-4}
Tacoma, WA	3.78×10^{-4}	1.30×10^{-4}
Calcined Target Material		
NWS Concord, CA	1.77×10^{-2}	5.82×10^{-3}
Long Beach, CA	1.60×10^{-2}	6.15×10^{-3}
Portland, OR	3.65×10^{-2}	8.50×10^{-3}
Tacoma, WA	4.74×10^{-2}	8.59×10^{-3}
Oxidized Target Material		
NWS Concord, CA	4.43×10^{-2}	1.46×10^{-2}
Long Beach, CA	4.01×10^{-2}	1.54×10^{-2}
Portland, OR	9.13×10^{-2}	2.13×10^{-2}
Tacoma, WA	1.19×10^{-1}	2.15×10^{-2}
From DOE Sites/Canadian Border		
BR-2 Belgium Spent Nuclear Fuel		
Alexandria Bay, NY	6.57×10^{-5}	1.83×10^{-5}
Hanford Site	1.13×10^{-4}	1.16×10^{-5}
Idaho National Engineering Laboratory	1.06×10^{-4}	9.48×10^{-6}
Nevada Test Site	1.33×10^{-4}	1.09×10^{-5}
Savannah River	5.10×10^{-5}	3.67×10^{-6}
Sweetgrass, MT	1.21×10^{-4}	2.12×10^{-5}
RHF France Spent Nuclear Fuel		
Alexandria Bay, NY	2.84×10^{-5}	7.91×10^{-6}
Hanford Site	4.86×10^{-5}	4.97×10^{-6}
Idaho National Engineering Laboratory	4.58×10^{-5}	4.07×10^{-6}
Nevada Test Site	5.73×10^{-5}	4.68×10^{-6}
Savannah River	2.21×10^{-5}	1.59×10^{-6}
Sweetgrass, MT	5.22×10^{-5}	9.11×10^{-6}
NRU Canada Spent Nuclear Fuel		
Alexandria Bay, NY	9.07×10^{-5}	2.53×10^{-5}
Hanford Site	1.56×10^{-4}	1.62×10^{-5}
Idaho National Engineering Laboratory	1.46×10^{-4}	1.33×10^{-5}
Nevada Test Site	1.83×10^{-4}	1.52×10^{-5}
Savannah River	7.03×10^{-5}	5.08×10^{-6}
Sweetgrass, MT	1.67×10^{-4}	2.95×10^{-5}
PRR-1 TRIGA Spent Nuclear Fuel		
Alexandria Bay, NY	1.77×10^{-4}	6.60×10^{-5}
Hanford Site	3.35×10^{-4}	7.04×10^{-5}
Idaho National Engineering Laboratory	3.16×10^{-4}	6.19×10^{-5}
Nevada Test Site	3.81×10^{-4}	6.60×10^{-5}
Savannah River	1.27×10^{-4}	1.31×10^{-5}
Sweetgrass, MT	3.76×10^{-4}	1.14×10^{-4}
Calcined Target Material		
Alexandria Bay, NY	1.04×10^{-2}	2.20×10^{-3}
Hanford Site	3.55×10^{-2}	6.78×10^{-3}
Idaho National Engineering Laboratory	3.38×10^{-2}	6.33×10^{-3}
Nevada Test Site	3.50×10^{-2}	6.35×10^{-3}
Savannah River	5.03×10^{-3}	5.03×10^{-4}
Sweetgrass, MT	4.51×10^{-2}	8.02×10^{-3}

Shipments to Oak Ridge Reservation:		
Source/Route	***Truck***	***Rail***
Oxidized Target Material		
Alexandria Bay, NY	2.61×10^{-2}	5.51×10^{-3}
Hanford Site	8.88×10^{-2}	1.70×10^{-2}
Idaho National Engineering Laboratory	8.47×10^{-2}	1.58×10^{-2}
Nevada Test Site	8.75×10^{-2}	1.59×10^{-2}
Savannah River	1.26×10^{-2}	1.26×10^{-3}
Sweetgrass, MT	1.13×10^{-1}	2.01×10^{-2}

Shipments to Savannah River Site:		
Source/Route	***Truck***	***Rail***
	From Eastern Ports	
BR-2 Belgium Spent Nuclear Fuel		
Charleston, SC (NWS)	8.42×10^{-6}	8.97×10^{-7}
Charleston, SC (Wando Terminal)	1.14×10^{-5}	8.97×10^{-7}
Elizabeth, NJ	5.89×10^{-5}	2.50×10^{-5}
Galveston, TX	8.20×10^{-5}	2.19×10^{-5}
Jacksonville, FL	9.46×10^{-6}	1.65×10^{-6}
Newport News, VA	3.16×10^{-5}	5.04×10^{-6}
Norfolk, VA	2.55×10^{-5}	3.77×10^{-6}
Philadelphia, PA	6.56×10^{-5}	1.65×10^{-5}
Portsmouth, VA	2.59×10^{-5}	3.27×10^{-6}
Savannah, GA	7.13×10^{-6}	5.84×10^{-7}
MOTSU, NC	6.37×10^{-6}	2.43×10^{-6}
Wilmington, NC	1.36×10^{-5}	2.32×10^{-6}
RHF France Spent Nuclear Fuel		
Charleston, SC (NWS)	3.64×10^{-6}	3.87×10^{-7}
Charleston, SC (Wando Terminal)	4.95×10^{-6}	3.87×10^{-7}
Elizabeth, NJ	2.54×10^{-5}	1.08×10^{-5}
Galveston, TX	3.55×10^{-5}	9.46×10^{-6}
Jacksonville, FL	4.09×10^{-6}	7.13×10^{-7}
Newport News, VA	1.37×10^{-5}	2.17×10^{-6}
Norfolk, VA	1.10×10^{-5}	1.63×10^{-6}
Philadelphia, PA	2.83×10^{-5}	7.13×10^{-6}
Portsmouth, VA	1.12×10^{-5}	1.41×10^{-6}
Savannah GA	3.08×10^{-6}	2.52×10^{-7}
MOTSU NC	2.75×10^{-6}	1.05×10^{-6}
Wilmington NC	5.90×10^{-6}	1.00×10^{-6}
NRU Canada Spent Nuclear Fuel		
Charleston, SC (NWS)	1.16×10^{-5}	1.24×10^{-6}
Charleston, SC (Wando Terminal)	1.58×10^{-5}	1.24×10^{-6}
Elizabeth, NJ	8.12×10^{-5}	3.45×10^{-5}
Galveston, TX	1.13×10^{-4}	3.02×10^{-5}
Jacksonville, FL	1.31×10^{-5}	2.28×10^{-6}
Newport News, VA	4.36×10^{-5}	6.96×10^{-6}
Norfolk, VA	3.52×10^{-5}	5.21×10^{-6}
Philadelphia, PA	9.04×10^{-5}	2.28×10^{-5}
Portsmouth, VA	3.57×10^{-5}	4.52×10^{-6}
Savannah, GA	9.83×10^{-6}	8.07×10^{-7}
MOTSU, NC	8.79×10^{-6}	3.36×10^{-6}
Wilmington, NC	1.88×10^{-5}	3.21×10^{-6}
PRR-1 TRIGA Spent Nuclear Fuel		
Charleston, SC (NWS)	2.14×10^{-5}	3.19×10^{-6}

Shipments to Savannah River Site:		
Source/Route	***Truck***	***Rail***
Charleston, SC (Wando Terminal)	$2.89x10^{-5}$	$3.19x10^{-6}$
Elizabeth, NJ	$1.54x10^{-4}$	$8.32x10^{-5}$
Galveston, TX	$2.05x10^{-4}$	$7.50x10^{-5}$
Jacksonville, FL	$2.56x10^{-5}$	$6.32x10^{-6}$
Newport News, VA	$8.21x10^{-5}$	$1.79x10^{-5}$
Norfolk, VA	$6.71x10^{-5}$	$1.37x10^{-5}$
Philadelphia, PA	$1.70x10^{-4}$	$5.58x10^{-5}$
Portsmouth, VA	$6.80x10^{-5}$	$1.20x10^{-5}$
Savannah, GA	$1.87x10^{-5}$	$2.22x10^{-6}$
MOTSU, NC	$1.73x10^{-5}$	$8.90x10^{-6}$
Wilmington, NC	$3.58x10^{-5}$	$8.52x10^{-6}$
HLW Vitrified		
Charleston, SC (NWS)	$1.27x10^{-4}$	$1.65x10^{-5}$
Charleston, SC (Wando Terminal)	$1.71x10^{-4}$	$1.65x10^{-5}$
Elizabeth, NJ	$1.19x10^{-3}$	$3.16x10^{-4}$
Galveston, TX	$1.21x10^{-3}$	$3.45x10^{-4}$
Jacksonville, FL	$2.93x10^{-4}$	$4.13x10^{-5}$
Newport News, VA	$6.64x10^{-4}$	$9.55x10^{-5}$
Norfolk, VA	$6.23x10^{-4}$	$7.95x10^{-5}$
Philadelphia, PA	$1.25x10^{-3}$	$2.28x10^{-4}$
Portsmouth, VA	$6.25x10^{-4}$	$7.24x10^{-5}$
Savannah, GA	$1.84x10^{-4}$	$1.44x10^{-5}$
MOTSU, NC	$1.98x10^{-4}$	$5.24x10^{-5}$
Wilmington, NC	$3.43x10^{-4}$	$5.04x10^{-5}$
Calcined Target Material		
Charleston, SC (NWS)	$1.15x10^{-3}$	$1.16x 10^{-4}$
Charleston, SC (Wando Terminal)	$1.33x10^{-3}$	$1.16x10^{-4}$
Elizabeth, NJ	$8.28x10^{-3}$	$2.17x10^{-3}$
Jacksonville, FL	$2.09x10^{-3}$	$2.96x10^{-4}$
Newport News, VA	$4.69x10^{-3}$	$6.69x10^{-4}$
Norfolk, VA	$4.41x10^{-3}$	$5.60x10^{-4}$
Philadelphia, PA	$8.79x10^{-3}$	$1.58x10^{-3}$
Portsmouth, VA	$4.42x10^{-3}$	$5.12x10^{-4}$
Savannah, GA	$1.30x10^{-3}$	$1.03x10^{-4}$
MOTSU, NC	$1.42x10^{-3}$	$3.71x10^{-4}$
Wilmington, NC	$2.43x10^{-3}$	$3.57x10^{-4}$
Galveston, TX	$8.43x10^{-3}$	$2.40x10^{-3}$
Oxidized Target Material		
Charleston, SC (NWS)	$2.88x10^{-3}$	$2.90x10^{-4}$
Charleston, SC (Wando Terminal)	$3.33x10^{-3}$	$2.90x10^{-4}$
Elizabeth, NJ	$2.07x10^{-2}$	$5.44x10^{-3}$
Jacksonville, FL	$5.23x10^{-3}$	$7.40x10^{-4}$
Newport News, VA	$1.17x10^{-2}$	$1.68x10^{-3}$
Norfolk, VA	$1.10x10^{-2}$	$1.40x10^{-3}$
Philadelphia, PA	$2.20x10^{-2}$	$3.95x10^{-3}$
Portsmouth, VA	$1.11x10^{-2}$	$1.28x10^{-3}$
Savannah, GA	$3.25x10^{-3}$	$2.57x10^{-4}$
MOTSU, NC	$3.54x10^{-3}$	$9.28x10^{-4}$
Wilmington, NC	$6.08x10^{-3}$	$8.93x10^{-4}$
Galveston, TX	$2.11x10^{-2}$	$6.00x10^{-3}$

Shipments to Savannah River Site:		
Source/Route	***Truck***	***Rail***
From Western Ports		
BR-2 Belgium Spent Nuclear Fuel		
NWS Concord, CA	1.52×10^{-4}	3.67×10^{-5}
Long Beach, CA	1.37×10^{-4}	3.15×10^{-5}
Portland, OR	1.80×10^{-4}	3.14×10^{-5}
Tacoma, WA	1.68×10^{-4}	3.29×10^{-5}
RHF France Spent Nuclear Fuel		
NWS Concord, CA	6.56×10^{-5}	1.58×10^{-5}
Long Beach, CA	5.94×10^{-5}	1.36×10^{-5}
Portland, OR	7.76×10^{-5}	1.35×10^{-5}
Tacoma, WA	7.24×10^{-5}	1.42×10^{-5}
NRU Canada Spent Nuclear Fuel		
NWS Concord, CA	2.09×10^{-4}	5.07×10^{-5}
Long Beach, CA	1.89×10^{-4}	4.37×10^{-5}
Portland, OR	2.48×10^{-4}	4.37×10^{-5}
Tacoma, WA	2.31×10^{-4}	4.57×10^{-5}
PRR-1 TRIGA Spent Nuclear Fuel		
NWS Concord, CA	3.90×10^{-4}	1.31×10^{-4}
Long Beach, CA	3.51×10^{-4}	1.46×10^{-4}
Portland, OR	5.00×10^{-4}	1.55×10^{-4}
Tacoma, WA	4.96×10^{-4}	1.59×10^{-4}
Calcined Target Material		
NWS Concord, CA	1.81×10^{-2}	4.78×10^{-3}
Long Beach, CA	1.61×10^{-2}	1.01×10^{-2}
Portland, OR	4.05×10^{-2}	1.02×10^{-2}
Tacoma, WA	5.15×10^{-2}	1.03×10^{-2}
Oxidized Target Material		
NWS Concord, CA	4.54×10^{-2}	1.20×10^{-2}
Long Beach, CA	4.03×10^{-2}	2.53×10^{-2}
Portland, OR	1.01×10^{-1}	2.54×10^{-2}
Tacoma, WA	1.29×10^{-1}	2.57×10^{-2}
From DOE Sites/Canadian Border		
BR-2 Belgium Spent Nuclear Fuel		
Alexandria Bay, NY	6.60×10^{-5}	4.27×10^{-5}
Hanford Site	1.61×10^{-4}	1.97×10^{-5}
Idaho National Engineering Laboratory	1.54×10^{-4}	1.76×10^{-5}
Nevada Test Site	1.81×10^{-4}	1.90×10^{-5}
Oak Ridge Reservation	5.10×10^{-5}	3.67×10^{-6}
Sweetgrass, MT	1.67×10^{-4}	2.85×10^{-5}
RHF France Spent Nuclear Fuel		
Alexandria Bay, NY	2.85×10^{-5}	1.85×10^{-5}
Hanford Site	6.94×10^{-5}	8.47×10^{-6}
Idaho National Engineering Laboratory	6.66×10^{-5}	7.57×10^{-6}
Nevada Test Site	7.81×10^{-5}	8.18×10^{-6}
Oak Ridge Reservation	2.21×10^{-5}	1.59×10^{-6}
Sweetgrass, MT	7.23×10^{-5}	1.23×10^{-5}
NRU Canada Spent Nuclear Fuel		
Alexandria Bay, NY	9.11×10^{-5}	5.90×10^{-5}
Hanford Site	2.22×10^{-4}	2.73×10^{-5}
Idaho National Engineering Laboratory	2.13×10^{-4}	2.44×10^{-5}
Nevada Test Site	2.49×10^{-4}	2.64×10^{-5}

Shipments to Savannah River Site:		
Source/Route	Truck	Rail
Oak Ridge Reservation	$7.03x10^{-5}$	$5.08x10^{-6}$
Sweetgrass, MT	$2.31x10^{-4}$	$3.97x10^{-5}$
PRR-1 TRIGA Spent Nuclear Fuel		
Alexandria Bay, NY	$1.78x10^{-4}$	$1.43x10^{-4}$
Hanford Site	$4.53x10^{-4}$	$9.49x10^{-5}$
Idaho National Engineering Laboratory	$4.34x10^{-4}$	$8.63x10^{-5}$
Nevada Test Site	$4.99x10^{-4}$	$9.04x10^{-5}$
Oak Ridge Reservation	$1.27x10^{-4}$	$1.31x10^{-5}$
Sweetgrass, MT	$4.90x10^{-4}$	$1.44x10^{-4}$
Calcined Target Material		
Alexandria Bay, NY	$1.07x10^{-2}$	$3.61x10^{-3}$
Hanford Site	$3.96x10^{-2}$	$7.11x10^{-3}$
Idaho National Engineering Laboratory	$3.79x10^{-2}$	$6.66x10^{-3}$
Nevada Test Site	$3.91x10^{-2}$	$6.68x10^{-3}$
Oak Ridge Reservation	$5.03x10^{-3}$	$5.03x10^{-4}$
Sweetgrass, MT	$4.91x10^{-2}$	$9.69x10^{-3}$
Oxidized Target Material		
Alexandria Bay, NY	$2.68x10^{-2}$	$9.05x10^{-3}$
Hanford Site	$9.90x10^{-2}$	$1.78x10^{-2}$
Idaho National Engineering Laboratory	$9.49x10^{-2}$	$1.67x10^{-2}$
Nevada Test Site	$9.77x10^{-2}$	$1.67x10^{-2}$
Oak Ridge Reservation	$1.26x10^{-2}$	$1.26x10^{-3}$
Sweetgrass, MT	$1.23x10^{-1}$	$2.42x10^{-2}$

The nonradiological risk factors are presented in terms of mortalities per shipment in Table E-10. Separate risk factors are provided for mortalities resulting from hydrocarbon emissions and transportation accidents (fatalities resulting from mechanical impact).

Table E-10 Vehicle-Related (Nonradiological) Risk Factors per Shipment to Spent Nuclear Fuel Types (Fatalities/Shipment)

Shipments to Hanford Site:			
Mode		Emission	Accident
From Eastern Ports			
Truck			
	Charleston, SC (NWS)	$1.11x10^{-5}$	$2.00x10^{-4}$
	Charleston, SC (Wando Terminal)	$1.18x10^{-5}$	$2.01x10^{-4}$
	Elizabeth, NJ	$1.31x10^{-5}$	$1.66x10^{-4}$
	Galveston, TX	$1.69x10^{-5}$	$1.50x10^{-4}$
	Jacksonville, FL	$1.44x10^{-5}$	$1.95x10^{-4}$
	Newport News, VA	$1.66x10^{-5}$	$1.80x10^{-4}$
	Norfolk, VA	$1.64x10^{-5}$	$1.83x10^{-4}$
	Philadelphia, PA	$1.42x10^{-5}$	$1.65x10^{-4}$
	Portsmouth, VA	$1.82x10^{-5}$	$1.82x10^{-4}$
	Savannah, GA	$1.36x10^{-5}$	$1.86x10^{-4}$
	Sunny Point, NC	$1.17x10^{-5}$	$1.82x10^{-4}$
	Wilmington, NC	$1.09x10^{-5}$	$2.10x10^{-4}$
Rail			
	Charleston, SC (NWS)	$2.35x10^{-5}$	$6.40x10^{-6}$
	Charleston, SC (Wando Terminal)	$2.35x10^{-5}$	$6.40x10^{-6}$
	Elizabeth, NJ	$5.58x10^{-5}$	$6.30x10^{-6}$
	Galveston, TX	$9.83x10^{-6}$	$5.00x10^{-6}$

Shipments to Hanford Site:			
Mode		***Emission***	***Accident***
	Jacksonville, FL	$2.01x10^{-5}$	$6.42x10^{-6}$
	Newport News, VA	$3.49x10^{-5}$	$6.46x10^{-6}$
	Norfolk, VA	$3.56x10^{-5}$	$6.67x10^{-6}$
	Philadelphia, PA	$5.38x10^{-5}$	$6.20x10^{-6}$
	Portsmouth, VA	$3.46x10^{-5}$	$6.60x10^{-6}$
	Savannah, GA	$1.86x10^{-5}$	$6.47x10^{-6}$
	Sunny Point, NC	$2.07x10^{-5}$	$6.70x10^{-6}$
	Wilmington, NC	$2.07x10^{-5}$	$6.68x10^{-6}$
		From Western Ports	
Truck			
	Concord, CA	$7.18x10^{-6}$	$4.81x10^{-5}$
	Long Beach, CA	$2.08x10^{-5}$	$7.74x10^{-5}$
	Portland, OR	$2.67x10^{-6}$	$1.04x10^{-5}$
	Tacoma, WA	$3.06x10^{-6}$	$1.03x10^{-5}$
Rail			
	Concord, CA	$1.99x10^{-5}$	$1.99x10^{-6}$
	Long Beach, CA	$3.67x10^{-5}$	$3.32x10^{-6}$
	Portland, OR	$4.48x10^{-6}$	$5.00x10^{-7}$
	Tacoma, WA	$5.61x10^{-6}$	$7.82x10^{-7}$
		From DOE Sites/Canadian Border	
Truck			
	Alexandria Bay, NY	$1.46x10^{-5}$	$1.49x10^{-4}$
	Idaho National Engineering Laboratory	$2.19x10^{-6}$	$3.07x10^{-5}$
	Nevada Test Site	$9.50x10^{-6}$	$6.38x10^{-5}$
	Oak Ridge Reservation	$9.50x10^{-6}$	$1.61x10^{-4}$
	Savannah River	$1.31x10^{-5}$	$1.81x10^{-4}$
	Sweetgrass, MT	$1.74x10^{-6}$	$4.15x10^{-5}$
Rail			
	Alexandria Bay, NY	$4.59x10^{-5}$	$6.02x10^{-6}$
	Idaho National Engineering Laboratory	$3.98x10^{-6}$	$1.38x10^{-6}$
	Nevada Test Site	$5.90x10^{-6}$	$2.72x10^{-6}$
	Oak Ridge Reservation	$1.45x10^{-5}$	$5.44x10^{-6}$
	Savannah River	$2.21x10^{-5}$	$6.18x10^{-6}$
	Sweetgrass MT	$3.98x10^{-6}$	$1.27x10^{-6}$

Shipments to Idaho National Engineering Laboratory:			
Mode		***Emission***	***Accident***
		From Eastern Ports	
Truck			
	Charleston, SC (NWS)	$1.03x10^{-5}$	$1.80x10^{-4}$
	Charleston, SC (Wando Terminal)	$1.09x10^{-5}$	$1.81x10^{-4}$
	Elizabeth, NJ	$1.17x10^{-5}$	$1.46x10^{-4}$
	Galveston, TX	$1.54x10^{-5}$	$1.30x10^{-4}$
	Jacksonville, FL	$1.22x10^{-5}$	$1.75x10^{-4}$
	Newport News, VA	$1.52x10^{-5}$	$1.60x10^{-4}$
	Norfolk, VA	$1.43x10^{-5}$	$1.63x10^{-4}$
	Philadelphia, PA	$1.28x10^{-5}$	$1.45x10^{-4}$
	Portsmouth, VA	$1.67x10^{-5}$	$1.62x10^{-4}$
	Savannah, GA	$1.22x10^{-5}$	$1.66x10^{-4}$
	Sunny Point, NC	$9.53x10^{-6}$	$1.59x10^{-4}$
	Wilmington, NC	$9.50x10^{-6}$	$1.89x10^{-4}$

Shipments to Idaho National Engineering Laboratory:			
Mode		Emission	Accident
Rail			
	Charleston, SC (NWS)	2.16×10^{-5}	5.26×10^{-6}
	Charleston, SC (Wando Terminal)	2.16×10^{-5}	5.26×10^{-6}
	Elizabeth, NJ	5.39×10^{-5}	5.15×10^{-6}
	Galveston, TX	7.91×10^{-6}	3.86×10^{-6}
	Jacksonville, FL	1.82×10^{-5}	5.28×10^{-6}
	Newport News, VA	3.30×10^{-5}	5.32×10^{-6}
	Norfolk, VA	3.37×10^{-5}	5.53×10^{-6}
	Philadelphia, PA	5.19×10^{-5}	5.05×10^{-6}
	Portsmouth, VA	3.26×10^{-5}	5.46×10^{-6}
	Savannah, GA	1.67×10^{-5}	5.33×10^{-6}
	Sunny Point, NC	1.88×10^{-5}	5.56×10^{-6}
	Wilmington, NC	1.88×10^{-5}	5.54×10^{-6}
From Western Ports			
Truck			
	Concord, CA	9.40×10^{-6}	5.52×10^{-5}
	Long Beach, CA	2.55×10^{-5}	6.21×10^{-5}
	Portland, OR	3.93×10^{-6}	3.62×10^{-5}
	Sweetgrass, MT	7.08×10^{-7}	2.89×10^{-5}
	Tacoma, WA	4.28×10^{-6}	3.97×10^{-5}
Rail			
	Concord, CA	9.08×10^{-6}	1.91×10^{-6}
	Long Beach, CA	3.48×10^{-5}	2.18×10^{-6}
	Portland, OR	5.36×10^{-6}	1.64×10^{-6}
	Sweetgrass, MT	5.06×10^{-6}	2.58×10^{-6}
	Tacoma, WA	8.62×10^{-6}	1.96×10^{-6}
From DOE Sites/Canadian Border			
Truck			
	Alexandria Bay, NY	1.32×10^{-5}	1.29×10^{-4}
	Hanford Site	2.19×10^{-6}	3.07×10^{-5}
	Nevada Test Site	8.08×10^{-6}	4.36×10^{-5}
	Oak Ridge Reservation	8.08×10^{-6}	1.41×10^{-4}
	Savannah River	1.17×10^{-5}	1.61×10^{-4}
Rail			
	Alexandria Bay, NY	4.40×10^{-5}	4.88×10^{-6}
	Hanford Site	3.98×10^{-6}	1.38×10^{-6}
	Nevada Test Site	3.98×10^{-6}	1.58×10^{-6}
	Oak Ridge Reservation	1.26×10^{-5}	4.30×10^{-6}
	Savannah River	2.01×10^{-5}	5.04×10^{-6}

Shipments to Nevada Test Site:			
Mode		Emission	Accident
From Eastern Ports			
Truck			
	Charleston, SC (NWS)	1.16×10^{-5}	1.92×10^{-4}
	Charleston, SC (Wando Terminal)	1.23×10^{-5}	1.94×10^{-4}
	Elizabeth, NJ	1.98×10^{-5}	1.87×10^{-4}
	Galveston, TX	1.90×10^{-5}	1.32×10^{-4}
	Jacksonville, FL	1.49×10^{-5}	1.88×10^{-4}
	Newport News, VA	1.79×10^{-5}	1.74×10^{-4}
	Norfolk, VA	1.70×10^{-5}	1.76×10^{-4}
	Philadelphia, PA	1.90×10^{-5}	1.85×10^{-4}

Shipments to Nevada Test Site:			
Mode		***Emission***	***Accident***
	Portsmouth, VA	1.94×10^{-5}	1.75×10^{-4}
	Savannah, GA	1.49×10^{-5}	1.79×10^{-4}
	Sunny Point, NC	1.57×10^{-5}	1.90×10^{-4}
	Wilmington, NC	1.22×10^{-5}	2.03×10^{-4}
Rail			
	Charleston, SC (NWS)	2.42×10^{-5}	6.16×10^{-6}
	Charleston, SC (Wando Terminal)	2.42×10^{-5}	6.16×10^{-6}
	Elizabeth, NJ	5.64×10^{-5}	6.06×10^{-6}
	Galveston, TX	6.44×10^{-6}	4.09×10^{-6}
	Jacksonville, FL	2.08×10^{-5}	6.18×10^{-6}
	Newport News, VA	3.56×10^{-5}	6.22×10^{-6}
	Norfolk, VA	3.63×10^{-5}	6.43×10^{-6}
	Philadelphia, PA	5.45×10^{-5}	5.96×10^{-6}
	Portsmouth, VA	3.52×10^{-5}	6.37×10^{-6}
	Savannah, GA	1.92×10^{-5}	6.23×10^{-6}
	Sunny Point, NC	2.14×10^{-5}	6.46×10^{-6}
	Wilmington, NC	2.14×10^{-5}	6.44×10^{-6}
		From Western Ports	
Truck			
	Concord, CA	1.59×10^{-5}	5.34×10^{-5}
	Long Beach, CA	2.06×10^{-5}	2.83×10^{-5}
	Portland, OR	1.20×10^{-5}	6.95×10^{-5}
	Tacoma, WA	1.16×10^{-5}	7.28×10^{-5}
Rail			
	Concord, CA	1.97×10^{-5}	1.78×10^{-6}
	Long Beach, CA	3.08×10^{-5}	1.01×10^{-6}
	Portland, OR	7.28×10^{-6}	2.99×10^{-6}
	Tacoma, WA	1.05×10^{-5}	3.30×10^{-6}
		From DOE Sites/Canadian Border	
Truck			
	Alexandria Bay, NY	1.62×10^{-5}	1.58×10^{-4}
	Hanford Site	9.50×10^{-6}	6.38×10^{-5}
	Idaho National Engineering Laboratory	8.08×10^{-6}	4.36×10^{-5}
	Oak Ridge Reservation	1.08×10^{-5}	1.54×10^{-4}
	Savannah River	1.43×10^{-5}	1.74×10^{-4}
	Sweetgrass, MT	9.59×10^{-6}	6.77×10^{-5}
Rail			
	Alexandria Bay, NY	4.66×10^{-5}	5.78×10^{-6}
	Hanford Site	5.90×10^{-6}	2.72×10^{-6}
	Idaho National Engineering Laboratory	3.98×10^{-6}	1.58×10^{-6}
	Oak Ridge Reservation	1.52×10^{-5}	5.20×10^{-6}
	Savannah River	2.27×10^{-5}	5.94×10^{-6}
	Sweetgrass, MT	7.03×10^{-6}	3.92×10^{-6}

Shipments to Oak Ridge Reservation:			
Mode		***Emission***	***Accident***
		From Eastern Ports	
Truck			
	Charleston, SC (NWS)	1.06×10^{-6}	3.81×10^{-5}
	Charleston, SC (Wando Terminal)	1.74×10^{-6}	3.94×10^{-5}
	Elizabeth, NJ	4.89×10^{-6}	5.42×10^{-5}
	Galveston, TX	6.60×10^{-6}	7.19×10^{-5}

Shipments to Oak Ridge Reservation:			
Mode		**Emission**	**Accident**
	Jacksonville, FL	2.29×10^{-6}	4.23×10^{-5}
	Newport News, VA	4.67×10^{-6}	3.66×10^{-5}
	Norfolk, VA	2.32×10^{-6}	3.64×10^{-5}
	Philadelphia, PA	7.95×10^{-6}	4.81×10^{-5}
	Portsmouth, VA	6.21×10^{-6}	3.79×10^{-5}
	Savannah, GA	9.33×10^{-7}	4.18×10^{-5}
	Sunny Point, NC	1.38×10^{-6}	4.66×10^{-5}
	Wilmington, NC	1.42×10^{-6}	4.94×10^{-5}
Rail			
	Charleston, SC (NWS)	3.60×10^{-6}	1.22×10^{-6}
	Charleston, SC (Wando Terminal)	3.60×10^{-6}	1.22×10^{-6}
	Elizabeth, NJ	4.00×10^{-5}	1.64×10^{-6}
	Galveston, TX	1.46×10^{-5}	2.20×10^{-6}
	Jacksonville, FL	5.61×10^{-6}	1.18×10^{-6}
	Newport News, VA	6.44×10^{-6}	1.60×10^{-6}
	Norfolk, VA	4.48×10^{-6}	1.44×10^{-6}
	Philadelphia, PA	2.46×10^{-5}	1.47×10^{-6}
	Portsmouth, VA	3.47×10^{-6}	1.38×10^{-6}
	Savannah, GA	4.06×10^{-6}	1.23×10^{-6}
	Sunny Point, NC	3.35×10^{-6}	1.13×10^{-6}
	Wilmington, NC	3.35×10^{-6}	1.11×10^{-6}
From Western Ports			
Truck			
	Concord, CA	2.31×10^{-5}	1.95×10^{-4}
	Long Beach, CA	2.78×10^{-5}	1.70×10^{-4}
	Portland, OR	1.25×10^{-5}	1.68×10^{-4}
	Tacoma, WA	8.56×10^{-6}	1.38×10^{-4}
Rail			
	Concord, CA	2.53×10^{-5}	5.88×10^{-6}
	Long Beach, CA	4.33×10^{-5}	5.59×10^{-6}
	Portland, OR	2.87×10^{-5}	5.91×10^{-6}
	Tacoma, WA	3.56×10^{-5}	5.93×10^{-6}
From DOE Sites/Canadian Border			
Truck			
	Alexandria Bay, NY	1.96×10^{-6}	6.31×10^{-5}
	Hanford Site	9.50×10^{-6}	1.61×10^{-4}
	Idaho National Engineering Laboratory	8.08×10^{-6}	1.41×10^{-4}
	Nevada Test Site	1.08×10^{-5}	1.54×10^{-4}
	Savannah River	2.96×10^{-6}	2.92×10^{-5}
	Sweetgrass, MT	6.98×10^{-6}	1.24×10^{-4}
Rail			
	Alexandria Bay, NY	2.78×10^{-5}	2.03×10^{-6}
	Hanford Site	1.45×10^{-5}	5.44×10^{-6}
	Idaho National Engineering Laboratory	1.26×10^{-5}	4.30×10^{-6}
	Nevada Test Site	1.52×10^{-5}	5.20×10^{-6}
	Savannah River	2.51×10^{-6}	8.72×10^{-7}
	Sweetgrass, MT	2.31×10^{-5}	4.39×10^{-6}

Shipments to Savannah River Site:			
	Mode	***Emission***	***Accident***
		From Eastern Ports	
Truck			
	Charleston, SC (NWS)	$5.15x10^{-7}$	$1.61x10^{-5}$
	Charleston, SC (Wando Terminal)	$1.19x10^{-6}$	$1.74x10^{-5}$
	Elizabeth, NJ	$5.47x10^{-6}$	$6.58x10^{-5}$
	Galveston, TX	$8.11x10^{-6}$	$7.15x10^{-5}$
	Jacksonville, FL	$3.22x10^{-8}$	$2.94x10^{-5}$
	Newport News, VA	$3.54x10^{-6}$	$4.57x10^{-5}$
	Norfolk, VA	$1.58x10^{-6}$	$4.45x10^{-5}$
	Philadelphia, PA	$9.37x10^{-6}$	$6.30x10^{-5}$
	Portsmouth, VA	$1.83x10^{-6}$	$4.47x10^{-5}$
	Savannah, GA	$3.22x10^{-8}$	$2.10x10^{-5}$
	Sunny Point, NC	$2.57x10^{-7}$	$2.17x10^{-5}$
	Wilmington, NC	$5.15x10^{-7}$	$2.87x10^{-5}$
Rail			
	Charleston, SC (NWS)	$1.46x10^{-6}$	$2.93x10^{-7}$
	Charleston, SC (Wando Terminal)	$1.46x10^{-6}$	$2.93x10^{-7}$
	Elizabeth, NJ	$3.92x10^{-5}$	$1.82x10^{-6}$
	Galveston, TX	$2.06x10^{-5}$	$2.46x10^{-6}$
	Jacksonville, FL	$2.80x10^{-6}$	$5.42x10^{-7}$
	Newport News, VA	$5.61x10^{-6}$	$1.26x10^{-6}$
	Norfolk, VA	$3.64x10^{-6}$	$1.11x10^{-6}$
	Philadelphia, PA	$2.39x10^{-5}$	$1.65x10^{-6}$
	Portsmouth, VA	$2.64x10^{-6}$	$1.04x10^{-6}$
	Savannah, GA	$5.86x10^{-7}$	$2.38x10^{-7}$
	Sunny Point, NC	$2.55x10^{-6}$	$7.99x10^{-7}$
	Wilmington, NC	$2.55x10^{-6}$	$7.80x10^{-7}$
		From Western Ports	
Truck			
	Concord, CA	$2.99x10^{-5}$	$1.96x10^{-4}$
	Long Beach, CA	$2.57x10^{-5}$	$1.68x10^{-4}$
	Portland, OR	$1.60x10^{-5}$	$1.88x10^{-4}$
	Tacoma, WA	$1.21x10^{-5}$	$1.59x10^{-4}$
Rail			
	Concord, CA	$4.80x10^{-5}$	$6.66x10^{-6}$
	Long Beach, CA	$5.07x10^{-5}$	$6.78x10^{-6}$
	Portland, OR	$3.44x10^{-5}$	$6.60x10^{-6}$
	Tacoma, WA	$4.13x10^{-5}$	$6.62x10^{-6}$
		From DOE Sites/Canadian Border	
Truck			
	Alexandria Bay, NY	$2.54x10^{-6}$	$7.47x10^{-5}$
	Hanford Site	$1.31x10^{-5}$	$1.81x10^{-4}$
	Idaho National Engineering Laboratory	$1.17x10^{-5}$	$1.61x10^{-4}$
	Nevada Test Site	$1.43x10^{-5}$	$1.74x10^{-4}$
	Oak Ridge Reservation	$2.96x10^{-6}$	$2.92x10^{-5}$
	Sweetgrass, MT	$1.05x10^{-5}$	$1.43x10^{-4}$
Rail			
	Alexandria Bay, NY	$5.76x10^{-5}$	$2.68x10^{-6}$
	Hanford Site	$2.21x10^{-5}$	$6.18x10^{-6}$
	Idaho National Engineering Laboratory	$2.01x10^{-5}$	$5.04x10^{-6}$
	Nevada Test Site	$2.27x10^{-5}$	$5.94x10^{-6}$

Shipments to Savannah River Site:			
	Mode	Emission	Accident
	Oak Ridge Reservation	$2.51x10^{-6}$	$8.72x10^{-7}$
	Sweetgrass, MT	$2.87x10^{-5}$	$5.07x10^{-6}$

The total risks for any alternative or option can be calculated by multiplying the number of foreign research reactor spent nuclear fuel shipments by the per-shipment risk factors provided in Tables E-8 through E-10.

E.7.1.2 Characterization of Shipment Risks

The results of the per-shipment analysis are shown in Tables E-8 through E-10. From these tables, it is clear that the incident-free dose would be much higher than the accident dose for each of the fuel types. The accident doses are based on realistic, yet conservative fuel loadings. Since most of the public dose would be from incident-free exposure, it is not overly conservative to assume, for assessment purposes, that all spent nuclear fuel can be represented by the fuel type with the highest risk factors for the remainder of the transportation analysis.

E.7.2 Evaluation of the Basic Implementation

The following sections describe the evaluation of the basic implementation of the Management Alternative 1 of the proposed action. The evaluation of the management and implementation alternatives are described in Section E.8.

E.7.2.1 Shipments

Under all SNF&INEL Final EIS (DOE, 1995) alternatives, the shipment of foreign research reactor spent nuclear fuel would require the movement of 837 casks from points of entry (marine ports and Canadian border crossings) to DOE facilities. The basic assumption used in determining the number of shipments is that spent nuclear fuel from countries bordering the Atlantic Ocean and Mediterranean Sea was assumed to arrive on the east coast of the United States, and spent nuclear fuel from countries bordering the Indian and Pacific Oceans was assumed to arrive on the west coast. This is conservative from an overland transportation standpoint, because, as shown in Tables E-8 through E-10, shipment to the coast nearest the management site would reduce the risk factors for the overland shipment. Additionally, this assumption is considered to be realistic because the long shipping times required to ship from the Pacific Ocean to east coast ports and from the Atlantic Ocean to west coast ports, would be costly in terms of shipping, and would tie up the world's already short supply of casks. The foreign research reactor spent nuclear fuel could arrive at any port that meets the criteria identified in Appendix D, and would be likely to arrive at a variety of these ports. The basic shipment count, by point of origin is:

	East Coast		West Coast		
	Aluminum	TRIGA	Aluminum	TRIGA	Totals
Phase 1	419	82	101	42	644
Phase 2	125	25	30	13	193
Totals	544	107	131	55	837

Several of the SNF&INEL Final EIS (DOE, 1995) alternatives involve consolidation of all spent nuclear fuel to Idaho National Engineering Laboratory and/or Savannah River Site and, therefore, are single-phase programs that would require no additional shipments. However, many of the possible options require the use of Hanford Site, Nevada Test Site and/or Oak Ridge Reservation; and, thus, would require intersite shipments. The number of intersite shipments is calculated based on the assumption that the equivalent of

10 seagoing foreign research reactor casks would fit into a single rail cask that would travel between DOE sites. Similarly, it is assumed that the contents of four foreign research reactor casks would fit into a single truck cask for intersite shipment. This is based on the distribution of cask capacities described in Appendix B. As described in Appendix B, there is considerable uncertainty in what storage mode would be used at the Phase 1 site, and therefore in what form the fuel would be for intersite shipment. Additionally, it is not clear what casks would be licensed and available when the intersite shipments would begin (approximately 2006). Therefore, these assumptions, which are neither definitely conservative nor nonconservative, are considered to be reasonable and realistic.

The number of intersite shipments for SNF&INEL Final EIS (DOE, 1995) alternatives that would require two-phased approaches varies between 13 and 161. The variation is caused by the large number of unique combinations of Phase 1 and Phase 2 approaches depending on the specific management sites selected. Additionally, the variation is affected by the assumption that larger truck and rail casks would be used for intersite shipments. The actual numbers of shipments are shown in Tables E-1 and E-2.

E.7.2.2 Evaluation Using Risk Factors

Since the fuel would actually arrive at a variety of ports, average shipment risk factors were calculated for east coast ports to each DOE site, and an average shipment risk factor for west coast ports to each DOE site. This approach does not require that a specific port be selected for analysis purposes. It instead models the average affect the foreign research reactor spent nuclear fuel acceptance policy might actually have on the public. This approach is conservative since the dose rates and curie content of the fuel used for the analyses were selected to be conservative, but as realistic as possible, since it is impossible to predict the distribution of shipments among the capable ports.

The upper and lower bound risk estimates for the foreign research reactor spent nuclear fuel policy were also calculated. The upper bound assumes that DOE chooses the acceptable port with the highest per-shipment risk factors for all shipments, and the lower bound risk estimates assume that DOE chooses the acceptable port with the lowest per-shipment risk factors. In general, the highest risk factors result from the longest shipments, and the smallest risk factors from the shortest shipments.

Impacts of Incident-Free Ground Transport

The incident-free transportation of spent nuclear fuel was estimated to result in total latent fatalities that ranged from 0.013 to 0.30 over the entire duration of the program. These fatalities are the sum of the estimated number of radiation-related LCF to the public and the crews.

The range of fatality estimates is caused by three factors: 1) the option of using truck or rail to transport spent nuclear fuel, 2) combinations of Phase 1 and Phase 2 sites that create varying shipment numbers and distances, and 3) the difference between the risk factors for the port-to-site routes.

The estimated number of radiation-related LCFs for transportation workers ranged from 0.006 to 0.071. The shipment by truck would yield higher crew exposures than the shipment by rail since the truck drivers would tend to sit closer to the cask than engineers. Doses to inspectors, security guards, and rail switchyard workers are also considered.

Truck and rail crew members are not radiation workers and, therefore, are not allowed to exceed a dosage of 100 mrem per yr. The regulatory limit for dose rate in occupied areas of the truck or train is 2 mrem per hr. Since a cross-country trip can take just over 50 hr of driving, if the radiation levels were at the maximum allowed, a driver could exceed his or her annual limit. Therefore, DOE would implement administrative controls beyond those required by Federal regulations to ensure that vehicle operators would not exceed their annual dose limits.

The public would be exposed to a small amount of radiation emanating from the cask, and also to pollutants associated with the diesel exhaust. The estimated number of radiation-related LCFs for the general population ranged from 0.007 to 0.22, and the estimated number of nonradiological fatalities from vehicular emissions ranged from 0.001 to 0.05. The fact that all these risk numbers are less than one means that the basic implementation would be unlikely to increase the total number of individuals that die of cancer in the United States (there are approximately 300,000 cancer deaths per yr in the United States) by a single fatality.

Impacts of Accidents During Ground Transport

The cumulative transportation accident risks over the entire program are estimated to range from 0.000004 to 0.00028 LCF from radiation and from 0.001 to 0.14 for traffic fatality, depending on the transportation mode and DOE sites selected. The reason for the range of fatality estimates is the same as those described for incident-free transportation. These risks, especially in the case of radiological accident risks, are much lower than those for incident-free transportation. The risk estimates are probabilistic, which means that they take the probability of an accident's occurring and the consequences of these accidents into account. The risk estimates indicate that the likelihood of a death or an injury from a vehicle accident not involving radiation or radioactive release would be much higher than a death from a radiation-related accident. Both indicate an expectation of less than one fatality.

The impacts of overland transportation for all alternatives and options are shown in Tables E-11 through E-19. As shown in Tables E-1 and E-2, there are 35 distinct approaches to the basic implementation of Management Alternative 1 of the proposed action. These 35 approaches are all the Phase 1/Phase 2 combinations allowed by the SNF&INEL Final EIS (DOE, 1995). Each of these 35 approaches is evaluated for three different transportation mode assumptions: 1) all shipments are on trucks, 2) that shipments from ports to sites are on trucks and intersite shipments are on rail, and 3) that all shipments are on rail. The transportation mode assumptions of all by truck and all by rail are analyzed to bound the risks of any combination of transportation modes. The third mode assumption is provided as an example of a realistic approach. Each distinct approach and mode assumption is evaluated using the average, upper bound, and lower bound risk factors.

These tables are designed to provide risk estimate factors for all expected implementation alternatives. For example, if the SNF&INEL Final EIS alternative selected is Centralization to Nevada Test Site, "Centralization" should be in the first column of each table, and "Nevada Test Site" in the second column of each table. The Phase 1 approaches available are listed in the third column. The decision as to which of the possible Phase 1 approaches would be used will be part of the foreign research reactor spent nuclear fuel policy described in this EIS. The risk estimates for the foreign research reactor spent nuclear fuel EIS policy are given for "Geographic" distribution of spent nuclear fuel during Phase 1 (to Idaho National Engineering Laboratory and Savannah River Site), for "By Fuel" distribution of spent nuclear fuel during Phase 1 (TRIGA to Idaho National Engineering Laboratory and aluminum-based to Savannah River Site), for "All to Idaho National Engineering Laboratory" during Phase 1, and for "All to Savannah River Site" during Phase 1. The risks, expressed in LCF and traffic accident fatalities are provided. These risk estimates include Phase 1 port-to-site shipments (Savannah River Site and/or Idaho National Engineering Laboratory), intersite shipments to, in this case, Nevada Test Site, and Phase 2 port-to-Nevada Test Site

Table E-11 Tabulation of Overland Transportation Risks: Basic Implementation. All Shipments via Truck, Average Risk Factors

Alternative / Option			Routine				Accidental
Programmatic SNF & INEL EIS Alternative	SNF Site Option	Phase I Approach	Radiological		Nonradiological		Radio-logical
			Crew	Public	Emis.	Traffic	
Decentralization	INEL/SRS		0.019	0.056	0.002	0.035	0.00002
1992/1993 Planning Basis	INEL/SRS		0.019	0.056	0.002	0.035	0.00002
Regionalization by Fuel Type	INEL/SRS		0.036	0.111	0.005	0.067	0.00004
Regionalization by Geography	INEL/SRS		0.019	0.056	0.002	0.035	0.00002
	INEL/ORR	Geographic	0.022	0.063	0.003	0.040	0.00005
		By Fuel	0.035	0.105	0.005	0.064	0.00007
		All to INEL	0.052	0.165	0.008	0.095	0.00006
	NTS/SRS	Geographic	0.020	0.060	0.003	0.038	0.00003
		By Fuel	0.033	0.102	0.005	0.062	0.00004
		All to SRS	0.030	0.091	0.005	0.056	0.00003
	NTS/ORR	Geographic	0.023	0.068	0.003	0.042	0.00006
		By Fuel	0.036	0.110	0.006	0.067	0.00008
		All to INEL	0.057	0.179	0.009	0.103	0.00009
		All to SRS	0.033	0.100	0.005	0.061	0.00007
	HS/SRS	Geographic	0.019	0.056	0.002	0.035	0.00002
		By Fuel	0.032	0.098	0.005	0.060	0.00004
		All to SRS	0.029	0.087	0.004	0.054	0.00003
	HS/ORR	Geographic	0.022	0.064	0.003	0.040	0.00005
		By Fuel	0.035	0.106	0.005	0.065	0.00007
		All to INEL	0.055	0.173	0.008	0.099	0.00007
		All to SRS	0.032	0.096	0.005	0.059	0.00007
Centralization	INEL		0.062	0.195	0.009	0.112	0.00007
	SRS		0.033	0.097	0.005	0.061	0.00003
	HS	Geographic	0.043	0.134	0.006	0.079	0.00015
		By Fuel	0.057	0.177	0.008	0.104	0.00017
		All to INEL	0.066	0.211	0.010	0.119	0.00008
		All to SRS	0.056	0.176	0.008	0.104	0.00019
	NTS	Geographic	0.042	0.127	0.007	0.080	0.00017
		By Fuel	0.055	0.170	0.009	0.105	0.00019
		All to INEL	0.067	0.212	0.011	0.123	0.00011
		All to SRS	0.054	0.167	0.009	0.104	0.00021
	ORR	Geographic	0.027	0.080	0.003	0.050	0.00008
		By Fuel	0.040	0.121	0.006	0.074	0.00009
		All to INEL	0.066	0.210	0.010	0.123	0.00016
		All to SRS	0.036	0.107	0.005	0.066	0.00008

All risks are expressed in latent cancer fatalities during the implementation of the policy, except for the Accidental-Traffic column, which is a number of fatalities.

Table E-12 Tabulation of Overland Transportation Risks: Basic Implementation, Shipments from Ports via Truck, Intersite Shipments via Rail, Average Risk Factors

Alternative / Option			Routine			Accidental	
Programmatic SNF & INEL EIS Alternative	SNF Site Option	Phase I Approach	Radiological Crew	Radiological Public	Nonradiological Emis.	Nonradiological Traffic	Radiological
Decentralization	INEL/SRS						
1992/1993 Planning Basis	INEL/SRS						
Regionalization by Fuel Type	INEL/SRS						
Regionalization by Geography	INEL/SRS						
	INEL/ORR	Geographic	0.020	0.058	0.003	0.036	0.00002
		By Fuel	0.033	0.100	0.005	0.061	0.00004
		All to INEL	0.052	0.165	0.008	0.095	0.00006
	NTS/SRS	Geographic	0.019	0.057	0.003	0.036	0.00002
		By Fuel	0.033	0.100	0.005	0.061	0.00003
		All to SRS	0.030	0.091	0.005	0.056	0.00003
	NTS/ORR	Geographic	0.020	0.059	0.003	0.037	0.00002
		By Fuel	0.034	0.102	0.005	0.062	0.00004
		All to INEL	0.054	0.166	0.008	0.096	0.00006
		All to SRS	0.031	0.093	0.005	0.057	0.00004
	HS/SRS	Geographic	0.018	0.054	0.002	0.034	0.00002
		By Fuel	0.032	0.096	0.005	0.059	0.00003
		All to SRS	0.029	0.087	0.004	0.054	0.00003
	HS/ORR	Geographic	0.019	0.056	0.003	0.035	0.00002
		By Fuel	0.033	0.098	0.005	0.060	0.00004
		All to INEL	0.053	0.163	0.008	0.095	0.00006
		All to SRS	0.030	0.089	0.004	0.055	0.00004
Centralization	INEL						
	SRS						
	HS	Geographic	0.032	0.094	0.005	0.055	0.00005
		By Fuel	0.045	0.136	0.008	0.080	0.00007
		All to INEL	0.064	0.200	0.010	0.114	0.00007
		All to SRS	0.042	0.128	0.007	0.075	0.00007
	NTS	Geographic	0.031	0.093	0.006	0.057	0.00006
		By Fuel	0.044	0.135	0.008	0.081	0.00007
		All to INEL	0.063	0.199	0.010	0.116	0.00007
		All to SRS	0.042	0.126	0.008	0.076	0.00008
	ORR	Geographic	0.023	0.067	0.003	0.041	0.00003
		By Fuel	0.036	0.109	0.005	0.066	0.00005
		All to INEL	0.056	0.174	0.009	0.101	0.00008
		All to SRS	0.033	0.100	0.005	0.061	0.00004

All risks are expressed in latent cancer fatalities during the implementation of the policy, except for the Accidental-Traffic column, which is a number of fatalities.

Table E-13 Tabulation of Overland Transportation Risks: Basic Implementation. All Shipments via Rail, Average Risk Factors

Alternative / Option			Routine			Accidental	
Programmatic SNF & INEL EIS Alternative	SNF Site Option	Phase I Approach	Radiological Crew	Radiological Public	Nonradiological Emis.	Nonradiological Traffic	Radio-logical
Decentralization	INEL/SRS		0.008	0.009	0.009	0.001	0.00001
1992/1993 Planning Basis	INEL/SRS		0.008	0.009	0.009	0.001	0.00001
Regionalization by Fuel Type	INEL/SRS		0.011	0.014	0.018	0.002	0.00001
Regionalization by Geography	INEL/SRS		0.008	0.009	0.009	0.001	0.00001
	INEL/ORR	Geographic	0.009	0.013	0.010	0.003	0.00001
		By Fuel	0.012	0.016	0.015	0.004	0.00001
		All to INEL	0.015	0.018	0.019	0.005	0.00001
	NTS/SRS	Geographic	0.009	0.014	0.011	0.004	0.00001
		By Fuel	0.012	0.018	0.016	0.005	0.00001
		All to SRS	0.011	0.018	0.016	0.005	0.00001
	NTS/ORR	Geographic	0.011	0.020	0.011	0.008	0.00004
		By Fuel	0.013	0.020	0.016	0.006	0.00002
		All to INEL	0.020	0.033	0.021	0.013	0.00005
		All to SRS	0.012	0.018	0.015	0.005	0.00002
	HS/SRS	Geographic	0.008	0.011	0.011	0.002	0.00001
		By Fuel	0.011	0.015	0.016	0.003	0.00001
		All to SRS	0.010	0.014	0.015	0.003	0.00001
	HS/ORR	Geographic	0.010	0.016	0.010	0.006	0.00004
		By Fuel	0.012	0.017	0.015	0.004	0.00002
		All to INEL	0.018	0.027	0.019	0.009	0.00002
		All to SRS	0.011	0.014	0.015	0.003	0.00001
Centralization	INEL		0.016	0.016	0.023	0.004	0.00002
	SRS		0.011	0.013	0.017	0.002	0.00001
	HS	Geographic	0.023	0.052	0.015	0.026	0.00012
		By Fuel	0.015	0.020	0.020	0.005	0.00004
		All to INEL	0.020	0.030	0.023	0.010	0.00003
		All to SRS	0.014	0.018	0.020	0.004	0.00004
	NTS	Geographic	0.022	0.049	0.016	0.027	0.00014
		By Fuel	0.016	0.024	0.021	0.007	0.00004
		All to INEL	0.022	0.036	0.024	0.014	0.00005
		All to SRS	0.015	0.021	0.020	0.006	0.00004
	ORR	Geographic	0.014	0.027	0.011	0.012	0.00005
		By Fuel	0.016	0.032	0.016	0.014	0.00004
		All to INEL	0.029	0.064	0.021	0.033	0.00012
		All to SRS	0.014	0.025	0.015	0.009	0.00002

All risks are expressed in latent cancer fatalities during the implementation of the policy, except for the Accidental-Traffic column, which is a number of fatalities.

Table E-14 Tabulation of Overland Transportation Risks: Basic Implementation, All Shipments via Truck, Lower Bound Risk Factors

Alternative / Option			Routine				Accidental
			Radiological		Nonradiological		Radio-
Programmatic SNF & INEL EIS Alternative	SNF Site Option	Phase I Approach	Crew	Public	Emis.	Traffic	logical
Decentralization	INEL/SRS		0.013	0.040	0.001	0.024	0.000007
1992/1993 Planning Basis	INEL/SRS		0.013	0.040	0.001	0.024	0.000007
Regionalization by Fuel Type	INEL/SRS		0.030	0.093	0.003	0.052	0.000012
Regionalization by Geography	INEL/SRS		0.013	0.040	0.001	0.024	0.000007
	INEL/ORR	Geographic	0.017	0.049	0.002	0.030	0.000039
		By Fuel	0.029	0.089	0.003	0.052	0.000045
		All to INEL	0.044	0.138	0.006	0.078	0.000020
	NTS/SRS	Geographic	0.014	0.043	0.002	0.026	0.000015
		By Fuel	0.027	0.084	0.003	0.048	0.000018
		All to SRS	0.025	0.075	0.003	0.042	0.000011
	NTS/ORR	Geographic	0.018	0.052	0.002	0.032	0.000048
		By Fuel	0.030	0.092	0.004	0.054	0.000052
		All to INEL	0.048	0.151	0.008	0.086	0.000055
		All to SRS	0.028	0.085	0.003	0.049	0.000053
	HS/SRS	Geographic	0.013	0.040	0.001	0.024	0.000009
		By Fuel	0.026	0.081	0.003	0.046	0.000013
		All to SRS	0.024	0.072	0.002	0.040	0.000011
	HS/ORR	Geographic	0.017	0.049	0.002	0.030	0.000041
		By Fuel	0.029	0.089	0.003	0.052	0.000047
		All to INEL	0.046	0.146	0.006	0.082	0.000029
		All to SRS	0.028	0.082	0.003	0.047	0.000052
Centralization	INEL		0.051	0.163	0.007	0.091	0.000023
	SRS		0.028	0.085	0.003	0.047	0.000012
	HS	Geographic	0.036	0.114	0.004	0.065	0.000127
		By Fuel	0.050	0.156	0.006	0.088	0.000135
		All to INEL	0.056	0.179	0.008	0.098	0.000032
		All to SRS	0.050	0.157	0.006	0.088	0.000161
	NTS	Geographic	0.034	0.105	0.005	0.065	0.000145
		By Fuel	0.047	0.146	0.007	0.087	0.000152
		All to INEL	0.056	0.177	0.009	0.100	0.000059
		All to SRS	0.047	0.146	0.007	0.087	0.000176
	ORR	Geographic	0.022	0.066	0.002	0.039	0.000063
		By Fuel	0.034	0.105	0.004	0.060	0.000065
		All to INEL	0.058	0.184	0.007	0.105	0.000122
		All to SRS	0.031	0.094	0.003	0.053	0.000053

All risks are expressed in latent cancer fatalities during the implementation of the policy, except for the Accidental-Traffic column, which is a number of fatalities.

Table E-15 Tabulation of Overland Transportation Risks: Basic Implementation, Shipments from Ports via Truck, Intersite Shipments via Rail, Lower Bound Risk Factors

Alternative / Option			Routine			Accidental	
Programmatic SNF & INEL EIS Alternative	SNF Site Option	Phase I Approach	Radiological		Nonradiological		Radio-logical
			Crew	Public	Emis.	Traffic	
Decentralization	INEL/SRS						
1992/1993 Planning Basis	INEL/SRS						
Regionalization by Fuel Type	INEL/SRS						
Regionalization	INEL/SRS						
by	INEL/ORR	Geographic	0.015	0.043	0.001	0.026	0.000011
Geography		By Fuel	0.028	0.084	0.003	0.048	0.000015
		All to INEL	0.044	0.138	0.006	0.078	0.000020
	NTS/SRS	Geographic	0.014	0.040	0.001	0.025	0.000008
		By Fuel	0.027	0.081	0.003	0.047	0.000012
		All to SRS	0.025	0.075	0.003	0.042	0.000011
	NTS/ORR	Geographic	0.015	0.043	0.002	0.027	0.000012
		By Fuel	0.028	0.084	0.003	0.049	0.000016
		All to INEL	0.044	0.138	0.007	0.079	0.000023
		All to SRS	0.026	0.078	0.003	0.045	0.000016
	HS/SRS	Geographic	0.013	0.038	0.001	0.023	0.000008
		By Fuel	0.026	0.079	0.003	0.045	0.000012
		All to SRS	0.024	0.072	0.002	0.040	0.000011
	HS/ORR	Geographic	0.014	0.041	0.001	0.025	0.000012
		By Fuel	0.027	0.082	0.003	0.047	0.000016
		All to INEL	0.043	0.136	0.006	0.077	0.000023
		All to SRS	0.025	0.075	0.002	0.043	0.000016
Centralization	INEL						
	SRS						
	HS	Geographic	0.025	0.074	0.004	0.042	0.000036
		By Fuel	0.038	0.115	0.005	0.063	0.000040
		All to INEL	0.053	0.168	0.008	0.093	0.000027
		All to SRS	0.036	0.109	0.005	0.059	0.000046
	NTS	Geographic	0.024	0.070	0.004	0.042	0.000035
		By Fuel	0.037	0.111	0.006	0.063	0.000040
		All to INEL	0.052	0.164	0.008	0.093	0.000026
		All to SRS	0.035	0.105	0.006	0.059	0.000045
	ORR	Geographic	0.018	0.052	0.002	0.031	0.000016
		By Fuel	0.031	0.093	0.003	0.052	0.000020
		All to INEL	0.048	0.148	0.007	0.083	0.000041
		All to SRS	0.029	0.087	0.003	0.048	0.000017

All risks are expressed in latent cancer fatalities during the implementation of the policy, except for the Accidental-Traffic column, which is a number of fatalities.

Table E-16 Tabulation of Overland Transportation Risks: Basic Implementation, All Shipments via Rail, Lower Bound Risk Factors

Alternative / Option			Routine				Accidental
			Radiological		Nonradiological		Radio-
Programmatic SNF & INEL EIS Alternative	SNF Site Option	Phase I Approach	Crew	Public	Emis.	Traffic	logical
Decentralization	INEL/SRS		0.006	0.007	0.008	0.001	0.000004
1992/1993 Planning Basis	INEL/SRS		0.006	0.007	0.008	0.001	0.000004
Regionalization by Fuel Type	INEL/SRS		0.010	0.011	0.014	0.002	0.000005
Regionalization	INEL/SRS		0.006	0.007	0.008	0.001	0.000004
by	INEL/ORR	Geographic	0.008	0.010	0.008	0.002	0.000007
Geography		By Fuel	0.010	0.013	0.012	0.003	0.000008
		All to INEL	0.013	0.013	0.013	0.004	0.000004
	NTS/SRS	Geographic	0.007	0.010	0.008	0.003	0.000005
		By Fuel	0.010	0.013	0.013	0.004	0.000005
		All to SRS	0.009	0.014	0.012	0.004	0.000005
	NTS/ORR	Geographic	0.010	0.016	0.008	0.007	0.000036
		By Fuel	0.011	0.016	0.012	0.005	0.000015
		All to INEL	0.017	0.027	0.015	0.012	0.000039
		All to SRS	0.010	0.014	0.012	0.004	0.000009
	HS/SRS	Geographic	0.006	0.008	0.008	0.001	0.000005
		By Fuel	0.009	0.011	0.012	0.002	0.000005
		All to SRS	0.009	0.011	0.012	0.002	0.000005
	HS/ORR	Geographic	0.009	0.013	0.008	0.005	0.000036
		By Fuel	0.010	0.013	0.012	0.003	0.000009
		All to INEL	0.015	0.022	0.013	0.008	0.000013
		All to SRS	0.009	0.011	0.012	0.002	0.000008
Centralization	INEL		0.013	0.011	0.015	0.003	0.000004
	SRS		0.009	0.011	0.013	0.002	0.000005
	HS	Geographic	0.021	0.048	0.011	0.025	0.000119
		By Fuel	0.013	0.015	0.015	0.004	0.000031
		All to INEL	0.017	0.023	0.016	0.008	0.000013
		All to SRS	0.012	0.014	0.015	0.003	0.000036
	NTS	Geographic	0.020	0.044	0.012	0.025	0.000131
		By Fuel	0.013	0.018	0.016	0.006	0.000035
		All to INEL	0.019	0.028	0.017	0.012	0.000039
		All to SRS	0.013	0.016	0.016	0.005	0.000034
	ORR	Geographic	0.012	0.025	0.008	0.010	0.000041
		By Fuel	0.015	0.029	0.012	0.012	0.000028
		All to INEL	0.027	0.059	0.014	0.031	0.000106
		All to SRS	0.013	0.023	0.012	0.007	0.000009

All risks are expressed in latent cancer fatalities during the implementation of the policy, except for the Accidental-Traffic column, which is a number of fatalities.

Table E-17 Tabulation of Overland Transportation Risks: Basic Implementation, All Shipments via Truck, Upper Bound Risk Factors

Alternative / Option			Routine			Accidental	
Programmatic SNF & INEL EIS Alternative	SNF Site Option	Phase I Approach	Radiological		Nonradiological		Radio-logical
			Crew	Public	Emis.	Traffic	
Decentralization	INEL/SRS		0.033	0.096	0.006	0.057	0.00007
1992/1993 Planning Basis	INEL/SRS		0.033	0.096	0.006	0.057	0.00007
Regionalization by Fuel Type	INEL/SRS		0.048	0.143	0.010	0.088	0.00011
Regionalization by Geography	INEL/SRS		0.033	0.096	0.006	0.057	0.00007
	INEL/ORR	Geographic	0.035	0.101	0.007	0.061	0.00010
		By Fuel	0.046	0.137	0.009	0.085	0.00013
		All to INEL	0.057	0.179	0.011	0.110	0.00012
	NTS/SRS	Geographic	0.034	0.101	0.007	0.060	0.00008
		By Fuel	0.046	0.137	0.010	0.083	0.00011
		All to SRS	0.044	0.129	0.010	0.078	0.00010
	NTS/ORR	Geographic	0.036	0.105	0.007	0.063	0.00011
		By Fuel	0.048	0.142	0.010	0.087	0.00014
		All to INEL	0.062	0.194	0.012	0.118	0.00016
		All to SRS	0.046	0.136	0.010	0.083	0.00014
	HS/SRS	Geographic	0.034	0.098	0.006	0.058	0.00007
		By Fuel	0.045	0.134	0.009	0.082	0.00010
		All to SRS	0.043	0.127	0.009	0.077	0.00010
	HS/ORR	Geographic	0.035	0.103	0.007	0.061	0.00010
		By Fuel	0.047	0.139	0.009	0.085	0.00013
		All to INEL	0.060	0.189	0.011	0.115	0.00013
		All to SRS	0.045	0.133	0.009	0.081	0.00014
Centralization	INEL		0.065	0.205	0.012	0.126	0.00014
	SRS		0.046	0.137	0.010	0.083	0.00011
	HS	Geographic	0.055	0.169	0.010	0.100	0.00020
		By Fuel	0.067	0.206	0.012	0.124	0.00024
		All to INEL	0.070	0.222	0.013	0.134	0.00015
		All to SRS	0.068	0.209	0.013	0.125	0.00026
	NTS	Geographic	0.054	0.161	0.011	0.100	0.00023
		By Fuel	0.065	0.198	0.013	0.124	0.00026
		All to INEL	0.071	0.222	0.014	0.137	0.00018
		All to SRS	0.066	0.199	0.014	0.125	0.00028
	ORR	Geographic	0.040	0.117	0.007	0.072	0.00013
		By Fuel	0.051	0.152	0.010	0.095	0.00016
		All to INEL	0.071	0.224	0.013	0.139	0.00023
		All to SRS	0.048	0.142	0.010	0.088	0.00014

All risks are expressed in latent cancer fatalities during the implementation of the policy, except for the Accidental-Traffic column, which is a number of fatalities.

Table E-18 Tabulation of Overland Transportation Risks: Basic Implementation, Shipments from Ports via Truck, Intersite Shipments via Rail, Upper Bound Risk Factors

Alternative / Option			Routine				Accidental
Programmatic SNF & INEL EIS Alternative	SNF Site Option	Phase I Approach	Radiological Crew	Radiological Public	Nonradiological Emis.	Nonradiological Traffic	Radiological
Decentralization	INEL/SRS						
1992/1993 Planning Basis	INEL/SRS						
Regionalization by Fuel Type	INEL/SRS						
Regionalization	INEL/SRS						
by	INEL/ORR	Geographic	0.033	0.095	0.006	0.057	0.00007
Geography		By Fuel	0.044	0.131	0.009	0.081	0.00010
		All to INEL	0.057	0.179	0.011	0.110	0.00012
	NTS/SRS	Geographic	0.034	0.098	0.007	0.058	0.00007
		By Fuel	0.045	0.134	0.009	0.082	0.00010
		All to SRS	0.044	0.129	0.010	0.078	0.00010
	NTS/ORR	Geographic	0.034	0.097	0.007	0.058	0.00007
		By Fuel	0.045	0.134	0.009	0.082	0.00010
		All to INEL	0.058	0.181	0.011	0.111	0.00013
		All to SRS	0.044	0.129	0.010	0.078	0.00010
	HS/SRS	Geographic	0.033	0.096	0.006	0.057	0.00007
		By Fuel	0.044	0.132	0.009	0.081	0.00010
		All to SRS	0.043	0.127	0.009	0.077	0.00010
	HS/ORR	Geographic	0.033	0.095	0.006	0.057	0.00007
		By Fuel	0.044	0.131	0.009	0.081	0.00010
		All to INEL	0.058	0.179	0.011	0.110	0.00013
		All to SRS	0.043	0.126	0.009	0.077	0.00010
Centralization	INEL						
	SRS						
	HS	Geographic	0.044	0.129	0.009	0.076	0.00011
		By Fuel	0.055	0.165	0.012	0.100	0.00014
		All to INEL	0.068	0.212	0.013	0.129	0.00015
		All to SRS	0.054	0.161	0.012	0.096	0.00015
	NTS	Geographic	0.043	0.126	0.010	0.077	0.00012
		By Fuel	0.054	0.163	0.012	0.101	0.00015
		All to INEL	0.067	0.209	0.013	0.130	0.00015
		All to SRS	0.053	0.158	0.013	0.097	0.00015
	ORR	Geographic	0.036	0.103	0.007	0.063	0.00008
		By Fuel	0.047	0.140	0.010	0.087	0.00011
		All to INEL	0.061	0.188	0.012	0.116	0.00015
		All to SRS	0.046	0.135	0.010	0.083	0.00011

All risks are expressed in latent cancer fatalities during the implementation of the policy, except for the Accidental-Traffic column, which is a number of fatalities.

Table E-19 Tabulation of Overland Transportation Risks: Basic Implementation, All Shipments via Rail, Upper Bound Risk Factors

Alternative / Option			Routine				Accidental
Programmatic SNF & INEL EIS Alternative	SNF Site Option	Phase I Approach	Radiological		Nonradiological		Radio-logical
			Crew	Public	Emis.	Traffic	
Decentralization	INEL/SRS		0.010	0.015	0.019	0.002	0.00003
1992/1993 Planning Basis	INEL/SRS		0.010	0.015	0.019	0.002	0.00003
Regionalization by Fuel Type	INEL/SRS		0.013	0.020	0.031	0.003	0.00004
Regionalization by Geography	INEL/SRS		0.010	0.015	0.019	0.002	0.00003
	INEL/ORR	Geographic	0.012	0.019	0.018	0.004	0.00003
		By Fuel	0.014	0.023	0.027	0.005	0.00004
		All to INEL	0.016	0.022	0.041	0.006	0.00005
	NTS/SRS	Geographic	0.012	0.022	0.020	0.005	0.00003
		By Fuel	0.014	0.025	0.028	0.006	0.00004
		All to SRS	0.014	0.026	0.025	0.006	0.00004
	NTS/ORR	Geographic	0.014	0.026	0.019	0.009	0.00006
		By Fuel	0.015	0.027	0.027	0.007	0.00005
		All to INEL	0.021	0.038	0.042	0.013	0.00008
		All to SRS	0.014	0.025	0.024	0.006	0.00004
	HS/SRS	Geographic	0.011	0.019	0.019	0.004	0.00003
		By Fuel	0.014	0.023	0.028	0.005	0.00004
		All to SRS	0.013	0.023	0.025	0.005	0.00004
	HS/ORR	Geographic	0.013	0.024	0.018	0.008	0.00006
		By Fuel	0.014	0.024	0.027	0.006	0.00004
		All to INEL	0.019	0.032	0.041	0.010	0.00006
		All to SRS	0.014	0.023	0.023	0.005	0.00004
Centralization	INEL		0.016	0.020	0.049	0.004	0.00005
	SRS		0.013	0.020	0.027	0.003	0.00004
	HS	Geographic	0.026	0.059	0.030	0.027	0.00015
		By Fuel	0.017	0.027	0.038	0.007	0.00007
		All to INEL	0.021	0.035	0.052	0.011	0.00006
		All to SRS	0.017	0.026	0.036	0.006	0.00007
	NTS	Geographic	0.025	0.056	0.027	0.028	0.00016
		By Fuel	0.018	0.030	0.035	0.008	0.00008
		All to INEL	0.023	0.040	0.049	0.014	0.00009
		All to SRS	0.017	0.028	0.032	0.007	0.00007
	ORR	Geographic	0.016	0.033	0.019	0.014	0.00007
		By Fuel	0.019	0.038	0.028	0.015	0.00007
		All to INEL	0.030	0.067	0.043	0.034	0.00015
		All to SRS	0.016	0.031	0.024	0.011	0.00005

All risks are expressed in latent cancer fatalities during the implementation of the policy, except for the Accidental-Traffic column, which is a number of fatalities.

shipments. Tables E-11 through E-13 present these risk estimates using average risk parameters. Tables E-14 through E-16 provide the lower bound risk estimates, and Tables E-17 through E-19 provide the upper bound risk estimates.

E.7.3 MEI Results for Routine Conditions

The risks to MEIs under incident-free transportation conditions have been estimated for the exposure scenarios described in Section E.6.7. The estimated dose to each of the receptors considered is presented in Table E-20 on a per-event basis (person-rem per event). Note that the potential exists for individual exposures if multiple exposure events occur. For instance, the dose to a person stuck in traffic next to a spent nuclear fuel shipment for 30 min is calculated to be 11 mrem. If the exposure duration was longer, the dose would rise proportionally. Therefore, it is conceivable that a person could receive a dose on the order of 30 to 50 mrem while stopped in traffic next to a shipment. In addition, a person working at a truck service station could receive a significant dose if trucks were to use the same stops repeatedly. If a truckstop worker was present for 100 shipment stops (at the distance and duration given above), the calculated dose is on the order of 30 mrem. Administrative controls could be instituted to control the location and duration of truck stops if multiple exposures were to happen routinely.

Table E-20 Estimated Doses (Rem/Event) to MEIs During Incident-free Transportation Conditions[a, b]

Receptor		*Dose to MEI*	
		Truck	*Rail*
Workers	Crew Member	0.1 rem/yr[c]	0.1 rem/yr[c]
	Inspector	0.0029 rem/event	0.0029 rem/event
	Rail Yard Crew Member	N/A	1.3×10^{-3} rem/event
Public	Resident	4.0×10^{-7} rem/event	4.0×10^{-7} rem/event
	Person in Traffic Obstruction	0.011 rem/event	0.011 rem/event
	Person at Service Station	0.00031 rem/event	N/A
	Resident Near Rail Stop	N/A	0.000013 rem/event

[a] *The exposure scenario assumptions are described in Section E.6.6.*

[b] *Doses are calculated assuming that the shipment external dose rate is equal to the regulatory limit of 10 mrem per hr at 2 m (6.6 ft) from the shipment.*

[c] *Dose to truck drivers could exceed the legal limit of rem per yr in the absence of administrative controls.*

The cumulative dose to a resident was calculated assuming all 837 shipments arrived at a single port or management site. The cumulative doses assume that the resident is present for every shipment and is unshielded at a distance of 30 m (66 ft) from the route. Therefore, the cumulative dose is only a function of the number of shipments passing a particular point and is independent of the actual site being considered. The maximum dose to this resident, if all the spent nuclear fuel were to be shipped to a single site, would be less than 0.1 mrem. The annual individual dose can be estimated by assuming that shipments would occur uniformly over a 15-year time period.

E.7.4 Accident Consequence Assessment - Maximum Severity Accident Results

The accident consequence assessment is intended to provide an estimate of the maximum potential impacts posed by the most severe potential transportation accidents involving a spent nuclear fuel shipment.

The accident consequence results are presented in Table E-21 for the maximum severity accidents as defined in the modal study. The population doses are for a uniform population density within an 80 km- (50 mi-) radius (Neuhuser and Kanipe, 1993). The location of the MEI is determined based on atmospheric conditions at the time of the accident and the buoyant characteristics of the released plume. The locations of maximum exposure would be 160 m (528 ft) and 400 m (1,320 ft) from the accident site for neutral and stable conditions, respectively. The dose to the MEI is independent of the location of the accident. In general, the dose to MEIs for the most severe accidents would be less than 10 mrem. No acute or early fatalities would be expected from radiological causes.

Table E-21 Potential Doses to Populations and MEIs for the Most Severe Transportation Accidents Involving Spent Nuclear Fuel[a,b]

	Neutral Conditions[c]				*Stable Conditions*[d]			
	Population[e]		*MEI*[f]		*Population*[e]		*MEI*[f]	
Mode and Accident Location	*Dose (person-rem)*	*Consequences (cancer fatalities)*	*Dose (rem)*	*Consequences (cancer fatality)*	*Dose (person-rem)*	*Consequences (cancer fatalities)*	*Dose (person-rem)*	*Consequences (cancer fatality)*
Truck								
Urban	14	0.007	0.0024	0.0000012	120	0.06	0.0079	0.000004
Suburban	2.7	0.0014	0.0024	0.0000012	21	0.01	0.0079	0.000004
Rural	0.15	0.000075	0.0024	0.0000012	1.2	0.0006	0.0079	0.000004
Rail								
Urban	14	0.007	0.0024	0.0000012	120	0.06	0.0079	0.000004
Suburban	2.7	0.0014	0.0024	0.0000012	21	0.01	0.0079	0.000004
Rural	0.15	0.000075	0.0024	0.0000012	1.2	0.0006	0.0079	0.000004

[a] *The most severe accidents correspond to the modal study accident severity category 6 (DOE, 1995).*

[b] *Buoyant plume rise resulting from fire for a severe accident was included in the exposure model.*

[c] *Neutral weather conditions result in moderate dispersion and dilution of the release plume. Neutral conditions were taken to be Pasquill stability Class D with a wind speed of 4 m per sec (9 mph). Neutral conditions occur approximately 50 percent of the time in the United States.*

[d] *Stable weather conditions result in minimal dispersion and dilution of the release plume and are thus unfavorable. Stable conditions were taken to be Pasquill stability Class F with a wind speed of 1 m per sec (2.2 mph). Stable conditions occur approximately one-third of the time in the United States.*

[e] *Populations extend at a uniform population density to a radius of 80 km (50 mi) from the accident site. Population exposure pathways include acute inhalation, acute cloudshine, groundshine, resuspended inhalation, resuspended cloudshine, and ingestion of food, including initially contaminated food (rural only). No decontamination or mitigative actions are taken.*

[f] *The MEI is assumed to be at the location of maximum exposure. The locations of maximum exposure would be 160 m (528 ft) and 400 m (1,320 ft) from the accident site under neutral and stable atmospheric conditions, respectively. Individual exposure pathways include acute inhalation, acute cloudshine, and groundshine during passage of the plume. No ingested dose is considered.*

The maximum foreseeable offsite transportation accident involves a shipment of spent nuclear fuel in a suburban population zone under neutral (average) weather conditions. The accident has a probability of occurrence of about 1 every 10,000,000 years and could result in 2.7 person-rem and no fatalities. The probability of an accident occurring is at least 10 times smaller in either an urban area or under stable atmospheric conditions, and the consequences are less than 10 times larger.